MELCOR

1959 THERMOELECTRICS 35th MELCOR Anniversary TRENTON, N.J. 1994

Frigichip® Thermoelectric Cooling Devices

Engineering Catalog

Over 30 years ago, MELCOR was the first to provide industry with practical thermoelectric coolers (TECs). Today, MELCOR remains the world leader, shipping more TECs around the globe than any other manufacturer. MELCOR's Frigichip® product line includes a full range of standard, single-stage TECs, as well as standard and custom multistage (cascade) TECs configured to meet the needs of specific applications. MELCOR can also provide fully configured, custom designed assemblies incorporating TECs with heatsinks, customer supplied parts, etc. MELCOR supports all of its products with extensive technical and design assistance.

MELCOR... World Leader in Thermoelectri

A Brief Introduction to Thermoelectrics

Thermoelectric coolers (TECs) are solid state heat pumps that utilize the Peltier effect. During operation, DC current flows through the TEC causing heat to be transferred from one side of the TEC to the other, creating a cold and hot side. A single-stage TEC can achieve temperature differences up to 70°C, or can transfer heat at a rate of 125 W. To achieve greater temperature differences (up to 132°C), select a multistage (cascade) TEC. To increase the amount of heat transferred, the TEC's modular design allows the use of multiple TECs mounted side-by-side. We know you have a lot of questions and we hope we've answered most of them on page 5. If not, give us a call or request our Engineering Catalog.

Benefits of MELCOR TECs

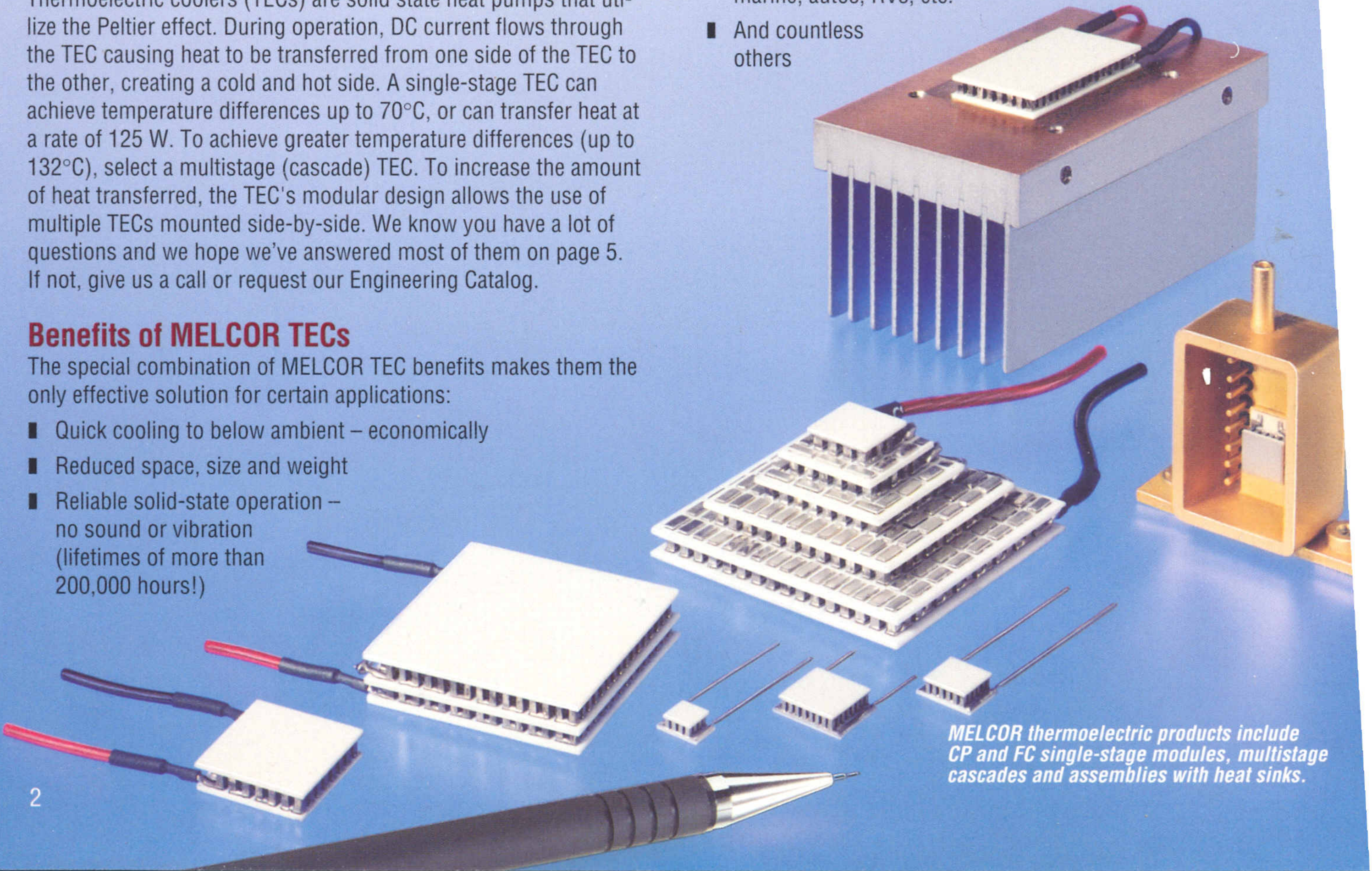
The special combination of MELCOR TEC benefits makes them the only effective solution for certain applications:

- Quick cooling to below ambient – economically
- Reduced space, size and weight
- Reliable solid-state operation – no sound or vibration (lifetimes of more than 200,000 hours!)
- Precision temperature control capability
- Minimum, if any, electrical noise
- DC operation
- Heat or cool by changing direction of current flow
- More than 150 standard types available, from sub-miniature, low capacity to compact, high-capacity
- Multistage cascades to -95°C, standard or designed to specifications

Broad Spectrum of TEC Applications

MELCOR TECs have been proven for three decades in a wide range of thermal management applications, including:

- Military/aerospace applications
- Fiber-optic, photonic and laser equipment
- Computers, PC boards and electronic packaging
- Laboratory and scientific instruments
- Medical and pharmaceutical equipment
- Chilled food/beverage dispensers
- Portable refrigerators/beverage coolers for home, marine, autos, RVs, etc.
- And countless others



MELCOR thermoelectric products include CP and FC single-stage modules, multistage cascades and assemblies with heat sinks.

FC Series Specifications

for low current, smaller heat pumping applications

	Catalog Number	IMAX (Amps)	QMAX [1] (Watts) TH = 25°C	VMAX (Volts) TH = 25°C	ΔTMAX (°C) TH = 25°C	N	Dimensions, mm A	B	C	D[2]
STANDARD	FC 0.45-4-05	0.80	0.22	0.48	67	4	1.8	3.4	3.4	2.4
	FC 0.45-8-05	0.80	0.43	0.97	67	8	3.4	3.4	5.0	2.4
	FC 0.45-12-05	0.80	0.65	1.45	67	12	3.4	5.0	5.0	2.4
	FC 0.45-18-05	0.80	0.97	2.18	67	18	5.0	5.0	6.6	2.4
	FC 0.45-32-05	0.80	1.72	3.87	67	32	6.6	6.6	8.3	2.4
	FC 0.45-66-05	0.80	3.56	7.98	67	66	9.9	9.1	11.5	2.4
	FC 0.6-4-06	1.20	0.32	0.48	67	4	2.2	4.2	4.2	2.7
	FC 0.6-8-06	1.20	0.65	0.97	67	8	4.2	4.2	6.2	2.7
	FC 0.6-12-06	1.20	0.97	1.45	67	12	4.2	6.2	6.2	2.7
	FC 0.6-18-06	1.20	1.46	2.18	67	18	6.2	6.2	8.3	2.7
	FC 0.6-32-06	1.20	2.59	3.87	67	32	8.3	8.3	10.3	2.7
	FC 0.6-66-06	1.20	5.34	7.98	67	66	12.3	11.3	14.4	2.7
	FC 0.6-4-05	1.50	0.40	0.48	67	4	2.2	4.2	4.2	2.4
	FC 0.6-8-05	1.50	0.81	0.87	67	8	4.2	4.2	6.2	2.4
	FC 0.6-12-05	1.50	1.21	1.45	67	12	4.2	6.2	6.2	2.4
	FC 0.6-18-05	1.50	1.82	2.18	67	18	6.2	6.2	8.3	2.4
	FC 0.6-32-05	1.50	3.23	3.87	67	32	8.3	8.3	10.3	2.4
	FC 0.6-66-05	1.50	6.67	7.98	67	66	12.3	11.3	14.4	2.4
	FC 0.65-4-04	2.00	0.54	0.48	67	4	2.2	4.2	4.2	2.2
	FC 0.65-8-04	2.00	1.08	0.97	67	8	4.2	4.2	6.2	2.2
	FC 0.65-12-04	2.00	1.62	1.45	67	12	4.2	6.2	6.2	2.2
	FC 0.65-18-04	2.00	2.43	2.18	67	18	6.2	6.2	8.3	2.2
	FC 0.65-32-04	2.00	4.31	3.87	67	32	8.3	8.3	10.3	2.2
	FC 0.65-66-04	2.00	8.89	7.98	67	66	12.3	11.3	14.4	2.2
OPTION ONE	FC 0.45-7-05-1	0.80	0.38	0.85	67	7	3.4	3.4	3.4	2.4
	FC 0.45-11-05-1	0.80	0.60	1.33	67	11	3.4	5.0	3.4	2.4
	FC 0.45-17-05-1	0.80	0.92	2.06	67	17	5.0	5.0	5.0	2.4
	FC 0.45-31-05-1	0.80	1.67	3.75	67	31	6.6	6.6	6.6	2.4
	FC 0.45-65-05-1	0.80	3.51	7.85	67	65	9.9	9.1	9.9	2.4
	FC 0.6-7-06-1	1.20	0.57	0.85	67	7	4.2	4.2	4.2	2.7
	FC 0.6-11-06-1	1.20	0.89	1.33	67	11	4.2	6.2	4.2	2.7
	FC 0.6-17-06-1	1.20	1.38	2.06	67	17	6.2	6.2	6.2	2.7
	FC 0.6-31-06-1	1.20	2.51	3.75	67	31	8.3	8.3	8.3	2.7
	FC 0.6-65-06-1	1.20	5.26	7.86	67	65	12.3	11.3	12.3	2.7
	FC 0.6-7-05-1	1.50	0.71	0.85	67	7	4.2	4.2	4.2	2.4
	FC 0.6-11-05-1	1.50	1.11	1.33	67	11	4.2	6.2	4.2	2.4
	FC 0.6-17-05-1	1.50	1.72	2.08	67	17	6.2	6.2	6.2	2.4
	FC 0.6-31-05-1	1.50	3.13	3.75	67	31	8.3	8.3	8.3	2.4
	FC 0.6-65-05-1	1.50	6.57	7.86	67	65	12.3	11.3	12.3	2.4
	FC 0.65-7-04-1	2.00	0.95	0.85	67	7	4.2	4.2	4.2	2.2
	FC 0.65-11-04-1	2.00	1.49	1.33	67	11	4.2	6.2	4.2	2.2
	FC 0.65-17-04-1	2.00	2.30	2.08	67	17	6.2	6.2	6.2	2.2
	FC 0.65-31-04-1	2.00	4.18	3.75	67	31	8.3	8.3	8.3	2.2
	FC 0.65-65-04-1	2.00	8.76	7.86	67	65	12.3	11.3	12.3	2.2
OPTION TWO	FC 0.45-4-05-2	0.80	0.22	0.48	67	4	1.8	3.4	5.1	2.4
	FC 0.45-8-05-2	0.80	0.43	0.97	67	8	3.4	3.4	5.1	2.4
	FC 0.45-12-05-2	0.80	0.65	1.45	67	12	3.4	5.0	6.7	2.4
	FC 0.45-18-05-2	0.80	0.97	2.18	67	18	5.0	5.0	6.7	2.4
	FC 0.45-32-05-2	0.80	1.72	3.87	67	32	6.6	6.6	8.3	2.4
	FC 0.45-66-05-2	0.80	3.56	7.98	67	66	9.9	9.1	10.8	2.4
	FC 0.6-4-06-2	1.20	0.32	0.48	67	4	2.2	4.2	6.3	2.7
	FC 0.6-8-06-2	1.20	0.65	0.97	67	8	4.2	4.2	6.3	2.7
	FC 0.6-12-06-2	1.20	0.97	1.45	67	12	4.2	6.2	8.3	2.7
	FC 0.6-18-06-2	1.20	1.46	2.18	67	18	6.2	6.2	8.3	2.7
	FC 0.6-32-06-2	1.20	2.59	3.87	67	32	8.3	8.3	10.4	2.7
	FC 0.6-66-06-2	1.20	5.34	7.98	67	66	12.3	11.3	13.4	2.7
	FC 0.6-4-05-2	1.50	0.40	0.48	67	4	2.2	4.2	6.3	2.4
	FC 0.6-8-05-2	1.50	0.81	0.87	67	8	4.2	4.2	6.3	2.4
	FC 0.6-12-05-2	1.50	1.21	1.45	67	12	4.2	6.2	8.3	2.4
	FC 0.6-18-05-2	1.50	1.82	2.18	67	18	6.2	6.2	8.3	2.4
	FC 0.6-32-05-2	1.50	3.23	3.87	67	32	8.3	8.3	10.4	2.4
	FC 0.6-66-05-2	1.50	6.67	7.98	67	66	12.3	11.3	13.4	2.4
	FC 0.65-4-04-2	2.00	0.54	0.48	67	4	2.2	4.2	6.3	2.2
	FC 0.65-8-04-2	2.00	1.08	0.97	67	8	4.2	4.2	6.3	2.2
	FC 0.65-12-04-2	2.00	1.62	1.45	67	12	4.2	6.2	8.3	2.2
	FC 0.65-18-04-2	2.00	2.43	2.18	67	18	6.2	6.2	8.3	2.2
	FC 0.65-32-04-2	2.00	4.31	3.87	67	32	8.3	8.3	10.4	2.2
	FC 0.65-66-04-2	2.00	8.89	7.98	67	66	12.3	11.3	13.4	2.2

CP Series Specifications

for higher current, larger heat pumping applications

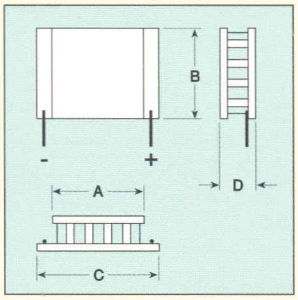
Catalog Number	IMAX (Amps)	QMAX [1] (Watts) TH = 25°C	VMAX (Volts) TH = 25°C	ΔTMAX (°C) TH = 25°C	N	Dimensions, mm A	B	C	D[2]
CP 0.8-7-06L	2.1	1.0	0.85	67	7	6	6	6	3.4
CP 0.8-17-06L	2.1	2.4	2.06	67	17	9	9	9	3.4
CP 0.8-31-06L	2.1	4.4	3.75	67	31	12	12	12	3.4
CP 0.8-63-06L	2.1	9.0	7.62	67	63	12	25	12	3.4
CP 0.8-71-06L	2.1	10.1	8.6	67	71	18	18	18	3.4
CP 0.8-127-06L	2.1	18.1	15.4	67	127	25	25	25	3.4
* CP 0.8-254-06L	2.1/4.2	36.2	30.8/15.4	67	254	50	25	50	3.4
CP 0.8-127-05L	2.6	22.4	15.4	67	127	25	25	25	3.1
* CP 0.8-254-05L	2.6/5.2	44.8	30.8/15.4	67	254	50	25	50	3.1
CP 1.0-7-08L	2.5	1.2	0.85	67	7	8	8	8	4.0
CP 1.0-17-08L	2.5	2.9	2.06	67	17	12	12	12	4.0
CP 1.0-31-08L	2.5	5.3	3.75	67	31	15	15	15	4.0
CP 1.0-63-08L	2.5	10.6	7.62	67	63	15	30	15	4.0
CP 1.0-71-08L	2.5	12.0	8.60	67	71	23	23	23	4.0
CP 1.0-127-08L	2.5	21.4	15.4	67	127	30	30	30	4.0
* CP 1.0-254-08L	2.5/5.0	42.8	30.8/15.4	67	254	60	30	60	4.0
CP 1.0-7-06L	3.0	1.4	0.85	67	7	8	8	8	3.6
CP 1.0-17-06L	3.0	3.4	2.06	67	17	12	12	12	3.6
CP 1.0-31-06L	3.0	6.3	3.75	67	31	15	15	15	3.6
CP 1.0-63-06L	3.0	12.7	7.62	67	63	15	30	15	3.6
CP 1.0-71-06L	3.0	14.4	8.60	67	71	23	23	23	3.6
CP 1.0-127-06L	3.0	25.7	15.4	67	127	30	30	30	3.6
* CP 1.0-254-06L	3.0/6.0	51.4	30.8/15.4	67	254	60	30	60	3.6
CP 1.0-7-05L	3.9	1.8	0.85	67	7	8	8	8	3.2
CP 1.0-17-05L	3.9	4.5	2.06	67	17	12	12	12	3.2
CP 1.0-31-05L	3.9	8.2	3.75	67	31	15	15	15	3.2
CP 1.0-63-05L	3.9	16.6	7.62	67	63	15	30	15	3.2
CP 1.0-71-05L	3.9	18.7	8.60	67	71	23	23	23	3.2
CP 1.0-127-05L	3.9	33.4	15.4	67	127	30	30	30	3.2
* CP 1.0-254-05L	3.9/7.8	66.8	30.8/15.4	67	254	60	30	60	3.2
CP 1.4-3-10L	3.9	0.8	0.36	70	3	5	10	5	4.7
CP 1.4-7-10L	3.9	1.8	0.85	70	7	10	10	10	4.7
CP 1.4-11-10L	3.9	2.9	1.33	70	11	10	15	10	4.7
CP 1.4-17-10L	3.9	4.5	2.06	70	17	15	15	15	4.7
CP 1.4-31-10L	3.9	8.2	3.75	70	31	20	20	20	4.7
CP 1.4-35-10L	3.9	9.2	4.24	70	35	15	30	15	4.7
CP 1.4-71-10L	3.9	18.7	8.60	70	71	30	30	30	4.7
CP 1.4-127-10L	3.9	33.4	15.4	70	127	40	40	40	4.7
CP 1.4-3-06L	6.0	1.2	0.36	67	3	5	10	5	3.8
CP 1.4-7-06L	6.0	2.8	0.85	67	7	10	10	10	3.8
CP 1.4-11-06L	6.0	4.4	1.33	67	11	10	15	10	3.8
CP 1.4-17-06L	6.0	6.9	2.06	67	17	15	15	15	3.8
CP 1.4-31-06L	6.0	12.5	3.75	67	31	20	20	20	3.8
CP 1.4-35-06L	6.0	14.2	4.24	67	35	15	30	15	3.8
CP 1.4-71-06L	6.0	28.7	8.60	67	71	30	30	30	3.8
CP 1.4-127-06L	6.0	51.4	15.4	67	127	40	40	40	3.8
CP 1.4-3-045L	8.5	1.6	0.36	67	3	5	10	5	3.3
CP 1.4-7-045L	8.5	3.8	0.85	67	7	10	10	10	3.3
CP 1.4-11-45L	8.5	6.0	1.33	67	11	10	15	10	3.3
CP 1.4-17-045L	8.5	9.2	2.06	67	17	15	15	15	3.3
CP 1.4-31-045L	8.5	16.8	3.75	67	31	20	20	20	3.3
CP 1.4-35-045L	8.5	19.0	4.24	67	35	15	30	15	3.3
CP 1.4-71-045L	8.5	38.5	8.60	67	71	30	30	30	3.3
CP 1.4-127-045L	8.5	68.8	15.4	67	127	40	40	40	3.3
CP 2-7-10L	9.0	4.2	0.85	70	7	15	15	15	5.6
CP 2-15-10L	9.0	9.1	1.82	70	15	15	30	15	5.6
CP 2-17-10L	9.0	10.3	2.06	70	17	22	22	22	5.6
CP 2-31-10L	9.0	18.8	3.75	70	31	30	30	30	5.6
CP 2-49-10L	9.0	29.7	5.93	70	49	36	36	36	5.6
CP 2-71-10L	9.0	43.1	8.60	70	71	44	44	44	5.6
CP 2-127-10L	9.0	77.1	15.4	70	127	62	62	62	5.6
CP 2-7-06L	14.0	6.6	0.85	67	7	15	15	15	4.6
CP 2-15-06L	14.0	14.2	1.82	67	15	15	30	15	4.6
CP 2-17-06L	14.0	16.0	2.06	67	17	22	22	22	4.6
CP 2-31-06L	14.0	29.3	3.75	67	31	30	30	30	4.6
CP 2-49-06L	14.0	46.2	5.93	67	49	36	36	36	4.6
CP 2-71-06L	14.0	67.0	8.60	67	71	44	44	44	4.6
CP 2-127-06L	14.0	120.0	15.4	67	127	62	62	62	4.6
CP 2.8-32-06L	24.0	51.8	3.87	67	32	40	40	40	5.0
CP 5-31-10L	39.0	81.5	3.75	70	31	55	55	55	5.8
CP 5-31-06L	60.0	125.0	3.75	67	31	55	55	55	4.9

Multistage (Cascade) Specifications

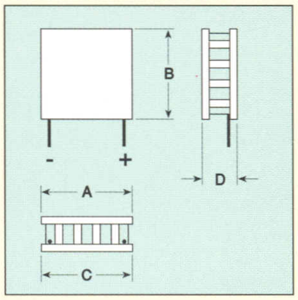
for greater temperature differentials

Catalog Number	I_{MAX} (Amps)	$T_H = 25°C$			Dimensions, mm				
		Q_{MAX} (1) (Watts)	V_{MAX} (Volts)	ΔT_{MAX} (°C)	A	B	C	D	E
2 CP 040 080-7-2	2.0	0.41	0.8	91	3.5	3.5	8	8	7.4
2 CP 040 065-31-17	2.1	3.11	3.8	81	11.5	11.5	15	15	6.6
2 CP 055 065-31-17	4.0	6.04	3.8	81	15	15	20	20	7.2
2 CP 085 100-31-20	5.9	9.74	3.8	77	23	26	30	30	10.7
2 CP 055 065-71-31	4.3	12.65	8.6	85	20	20	30	30	7.2
2 SC 040 050-127-63	2.8	16.05	15.5	83	30	30	30	30	7.1
2 CP 085 065-71-31	10.3	30.22	8.6	85	30	30	44	44	8.9
2 SC 055 045-127-63	6.0	34.51	15.5	83	40	40	40	40	7.5
2 SC 085 065-127-70	9.5	59.25	15.5	81	62	62	62	62	8.9
3 CP 040 065-31-17-7	1.8	1.52	3.8	96	8	8	15	15	9.5
3 CP 040 065-127-71-31	1.8	6.48	15.4	96	15	15	30	30	9.5
3 CP 055 065-71-31-17	3.5	6.53	7.7	97	15	15	30	30	10.4
3 CP 055 065-127-71-31	3.5	12.58	15.4	96	20	20	40	40	10.4
3 CP 085 065-71-31-17	8.4	15.60	7.7	97	22	22	44	44	12.9
4 CP 040 080-64-26-11-6	1.4	1.08	6.8	110	4	11	16	23.6	14.0
4 CP 040 080-31-17-7-2	1.5	0.47	3.8	114	3.5	3.5	15	15	14.0
4 CP 040 065-71-31-17-7	1.7	1.66	7.9	110	8	8	23	23	12.5
4 CP 055 065-69-29-11-6	3.4	2.68	7.5	112	4.5	14.5	24	33	13.8
4 CP 040 080-127-71-31-17	1.3	2.87	14.6	107	11.5	11.5	30	30	14.0
4 CP 055 065-127-71-31-17	3.1	6.84	14.6	107	15	15	40	40	13.8
5 CP 040 065-127-71-31-17-7	1.6	1.74	14.5	118	8	8	30	30	15.4
5 CP 055 065-127-71-31-17-7	3.0	3.37	14.5	118	10	10	40	40	16.9
6 CP 040 065-127-71-31-17-7-2	1.5	0.63	14.5	131	3.5	3.5	30	30	18.3
6 CP 055 065-127-71-31-17-7-2	3.0	1.22	14.5	131	5	5	40	40	20.1

FC SERIES - STANDARD



FC SERIES - OPTION ONE



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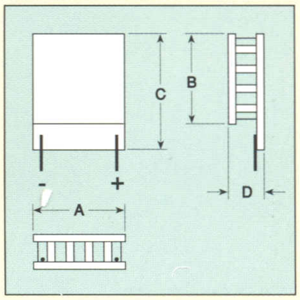
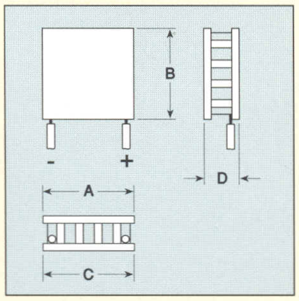
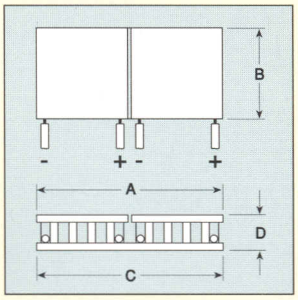


CP SERIES

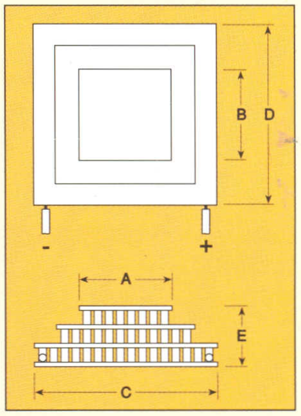


*CP _ _-254-_ _



These modules have four leads and can be wired in series or parallel. The Specifications table indicates maximum values for V and I when "Wired in Series"/"Wired in Parallel."

TYPICAL MULTISTAGE (CASCADE)



Interfacing:

Both hot and cold faces lapped flat, TYPE L. Both faces metallized and tinned, TYPE TT. Hybrid, hot face tinned, cold face lapped, TYPE TL. Hot face lapped, cold face tinned, TYPE LT. Two face soldering (Type TT) in sizes larger than 12 x 12 mm is not recommended. Consult MELCOR for details.

Wire Standards:

Module Type	Wire Gauge (AWG)	Module Type	Wire Gauge (AWG)
FC 0.45-ALL	32	CP 2-ALL	18
FC 0.6-ALL	30	CP 2.8-ALL	16
FC 0.65-ALL	30	CP 5-_ _-10	14
CP 0.8-ALL	26	CP 5-_ _-06	12
CP 1.0-ALL	24	CP _ _-254-_ _	Contact MELCOR
CP 1.4-ALL	18	Multistage	Contact MELCOR

For all FC Series modules, wire is solid, uninsulated and 50 mm (2.0 in.) long.

For all CP Series modules, wire is stranded, 114 mm (4.5 in.) long and PVC insulated.

Notes:

(1) Q_{MAX} rated value at $\Delta T = 0°$, I_{MAX} and V_{MAX}, $T_H = 25°C$

(2) Thickness (D) for Type L only.

Definitions:

- I_{MAX} Input current resulting in greatest ΔT (ΔT_{MAX}) [Amps]
- N Number of thermocouples (p- and n-type pairs)
- Q_{MAX} Maximum amount of heat that can be absorbed at cold face (occurs at $I = I_{MAX}$, $\Delta T = 0$) [Watts]
- T_H Temperature of the TEC hot face during operation [°C]
- ΔT_{MAX} Maximum temperature difference a TEC can achieve (occurs at $I = I_{MAX}$, $Q_C = 0$) [°C]
- V_{MAX} Voltage at ΔT_{MAX}

What Everyone Asks Us About Thermoelectrics

"I'm curious, exactly what is a thermoelectric module?"

A thermoelectric module is a small solid state device that can operate as a heat pump or as an electrical power generator. When used to generate electricity, the module is called a thermoelectric generator (TEG). When used as a heat pump, the module utilizes the Peltier effect to move heat and is called a thermoelectric cooler (TEC). MELCOR is the world leader in TEC manufacturing. (Our products are also well suited for some TEG applications. However, we address only TECs in this literature.)

"It sounds familiar, but...what is the Peltier effect?"

The Peltier effect was discovered in 1834. When current passes through the junction of two different types of conductors it results in a temperature change. However, the practical application of this concept required the development of semiconductors that are good conductors of electricity but poor conductors of heat – the perfect balance for TEC performance. Today, bismuth telluride is primarily used as the semiconductor material, heavily doped to create either an excess (n-type) or a deficiency (p-type) of electrons.

"How does a TEC work?"

Very simply, a TEC consists of a number of p- and n-type pairs (couples) connected electrically in series and sandwiched between two ceramic plates (see drawing). When connected to a DC power source, current causes heat to move from one side of the TEC to the other. Naturally, this creates a hot side and a cold side on the TEC. A typical application exposes the cold side of the TEC to the object or substance to be cooled and the hot side to a heatsink which dissipates the heat to the environment. A heat exchanger with forced air or liquid may be required. (As clever as TECs are, they can't eat heat – only move it!)

"What happens if I reverse the direction of the current?"

If the current is reversed, the heat is moved in the opposite direction. In other words, what was the hot face will become the cold face and vice-versa.

"How much heat can it pump? Could I cool my house with it?"

The maximum amount of heat the largest single TEC can pump is about 125 W. So, you wouldn't cool your house with it! However, our modular design enables you to use several TECs per application, allowing you to move more heat.

"So, I can use more than just one?"

Sure! They can be used side-by-side to increase the amount of heat pumped, or they can be stacked on top of one another to increase the temperature difference across the TEC. When stacked, they are called "cascades," or multistage TECs. When the temperature difference between the hot and cold faces doesn't need to be more than about 60°C, single-stage TECs can normally do the job. If the temperature difference needs to be greater than 60°C, cascades should be considered. Some cascades are listed in the Multistage Specification table. Many others are also available.

"When should I use a TEC? Is a TEC as good as a compressor?"

TECs are absolutely perfect for some applications and completely unsuitable for others. Depending on the application, a TEC can be much, much better than a compressor or no match at all! TECs are very small, very light weight, and completely silent. With no moving parts, they are extraordinarily reliable. TECs generate little, if any, electrical noise and can provide precision temperature control when used with an appropriate controller. They can be operated in a vacuum or weightless environments, and in any physical orientation. On the other hand, TECs tend to lose their competitive advantage when cooling loads exceed 200 W. Under some special circumstances, however, TECs are used to pump loads of tens of kilowatts.

"Is it hard to design-in a TEC?"

Not really. It does require some understanding of heat transfer and a good grasp of your application. Selection/Performance graphs and an example are shown on page 6. Our Engineering Catalog explains in far greater detail how TECs work and how to select the one best suited for your application. Our experienced engineers are available to help you.

"Do I need special equipment or training to install a TEC?"

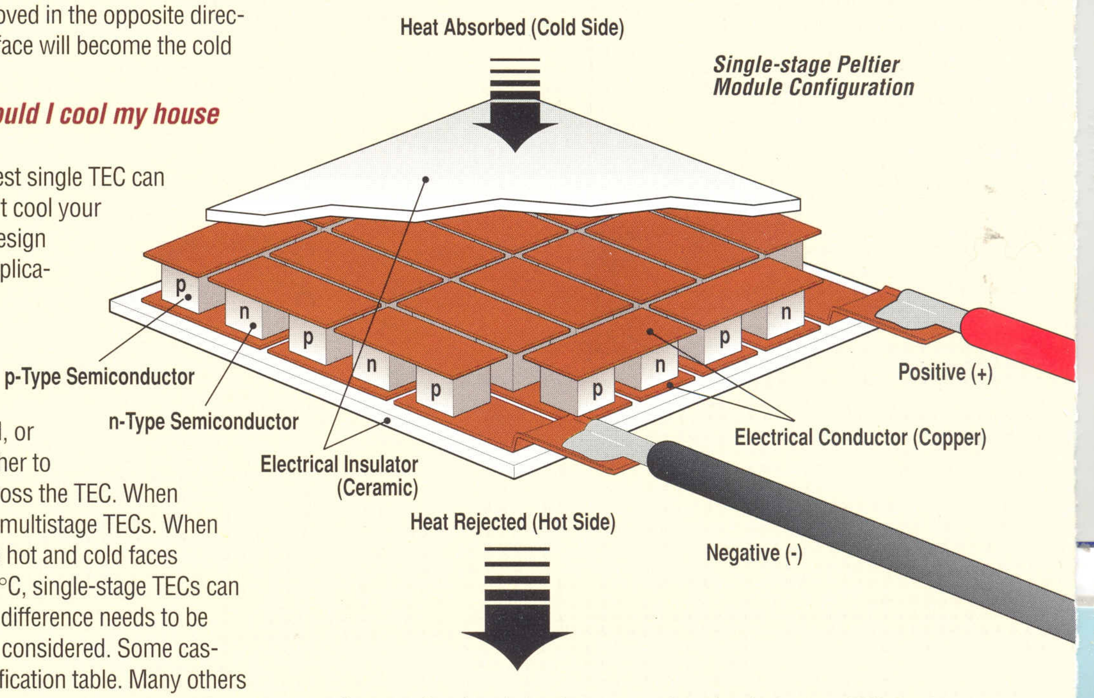
Proper installation is extremely important but not very difficult. MELCOR provides detailed, illustrated assembly instructions. And, we can build custom subassemblies for specific applications.

"What about temperature control and power supplies?"

TECs are DC devices. The amount of heat pumped through the TEC is directly proportional to the power supplied. Temperature is controlled through manual or automatic means. The automatic controller can range from a simple on-off thermostat to a complex computer controlled feedback circuit. Such control systems are available from a variety of qualified manufacturers.

"This may be just what I'm looking for. How can I get an Engineering Catalog?"

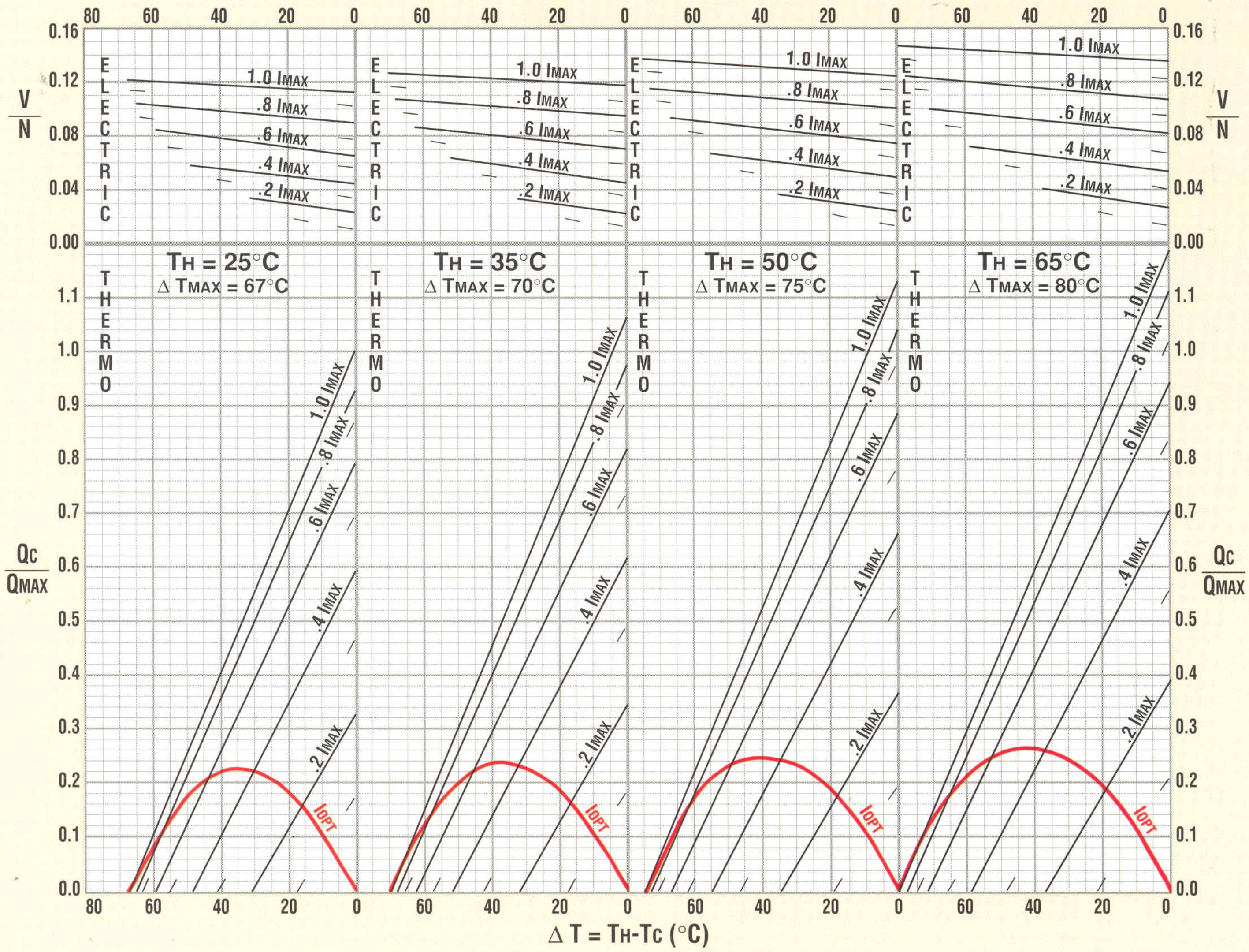
Just drop the enclosed reply card in the mail or give us a call!



Cutaway drawing shows the construction of a single-stage TEC. During operation, DC current flows through the p- and n-type couples causing heat to move from the cold side to the hot side of the TEC. In many applications, some type of heat exchanger will be used on the hot side of the TEC to move heat away from the unit.

Place our order

Selection/Performance (S/P) Graphs



I	Input current [Amps]	Qc	Amount of heat absorbed at cold face of TEC [Watts]	ΔT	Temperature difference between TEC faces, TH - TC [°C]
IOPT	Optimum (most efficient) input current required for a given ΔT [Amps]	QMAX	Maximum amount of heat that can be absorbed at cold face (occurs at I = IMAX, ΔT = 0) [Watts]	ΔTMAX	Maximum temperature difference a TEC can achieve (occurs at I = IMAX, Qc = 0) [°C]
IMAX	Input current resulting in greatest ΔT (ΔTMAX) [Amps]	Tc	Temperature of the TEC cold face during operation [°C]	V	Input Voltage [Volts]
N	Number of thermocouples (p- and n-type pairs)	TH	Temperature of the TEC hot face during operation [°C]	VMAX	Voltage at ΔTMAX

TEC SELECTION

(Use the *Thermo section* of S/P Graph)

Before beginning the TEC selection process, three application parameters must be known: TH, Tc and Qc. ***For this example, TH = 37° C, Tc = 5° C and Qc = 30 W.***

1. Calculate ΔT = TH - Tc. ***ΔT = 37 - 5 = 32° C***

2. Choose the S/P Graph with TH ≤ TH of the application; read ΔTMAX. (If the application's ΔT ≥ ΔTMAX, a multistage TEC is required. Contact a MELCOR application engineer for assistance.) ***Select S/P Graph with TH = 35° C; ΔTMAX = 70° C.***

3. Locate ΔT at the top or bottom of the selected graph. At ΔT, draw a vertical line through the entire graph. ***Draw vertical line at ΔT= 32° C.***

4. Locate intersection of ΔT and IOPT curve. Read IOPT. ***At ΔT = 32° C, IOPT = 0.4 IMAX.***

5. Select an operating current (ISELECT) between IOPT and IMAX. When there are no special design constraints, a practical choice would be midway between IOPT and IMAX where ISELECT = (IOPT + IMAX) / 2. ***ISELECT = (0.4 IMAX + 1.0 IMAX) / 2 = 0.7 IMAX.***

6. At intersection of ΔT and 1.0 IMAX, draw a horizontal line through the graph and determine Qc/QMAX for IMAX. ***Draw horizontal line through (ΔT= 32° C, 1.0 IMAX). Line intersects vertical axis at Qc/QMAX = 0.58.***

7. Repeat Step 6 for IOPT. ***Draw horizontal line through (ΔT= 32° C, IOPT). Line intersects vertical axis at Qc/QMAX = 0.23.***

8. Repeat Step 6 for ISELECT. ***Draw horizontal line through (ΔT= 32° C, 0.7 IMAX). Line intersects vertical axis at Qc/QMAX= 0.46.***

9. Knowing Qc, solve for QMAX corresponding to IMAX, IOPT and ISELECT. QMAX = Qc / [Qc/QMAX]. ***At IMAX, QMAX = 30/0.58 = 51.7 W. At IOPT, QMAX= 30/0.23 = 130.4 W. At ISELECT, QMAX = 30/0.46 = 65.2 W.***

10. Refer to the Specification Tables and select the TEC(s) having a QMAX near the QMAX for ISELECT. Any TEC with values falling between the IOPT and IMAX selection boundaries will suffice. The IMAX boundary represents a lower TEC unit cost, highest input power design. The IOPT boundary represents a higher TEC unit cost, lowest input power design. ***Select the CP 1.0-254-05L, CP 1.4-127-045L or CP 2-71-06L. The QMAX value for each is close to 65.2 W, and between 51.7 and 130.4 W.***

TEC PERFORMANCE

(Use the *Thermo and Electric sections* of S/P Graph)

To evaluate the performance of a chosen single-stage TEC, convert the universal S/P Graph values to those of the TEC and re-label the graph. (For this step, we recommend use of our S/P Graph worksheets, included in the Engineering Catalog.) To determine Qc, multiply Qc/QMAX by the TEC's QMAX value. To determine V, multiply V/N values by the TEC's N value. To determine I, use the TEC's IMAX to compute values for .__ IMAX. ***For the CP 2-71-06L: QMAX = 67.0 W, IMAX = 14.0 A and N = 71. So, Qc = 0.1 x 67 = 6.7 W, 0.2 x 67 = 13.4 W... And, V = 0.04 x 71 = 2.84 V, 0.08 x 71 = 5.68 V... And, I = .2 x 14.0 = 2.8 A, .4 x 5.6 A...***

For further details, request our Engineering Catalog which fully explains TEC Selection and Performance, including illustrated examples and convenient full-page S/P Graph worksheets.

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Table of Contents

THERMOELECTRIC COOLING PRODUCTS available from MELCOR

WHAT ARE THERMOELECTRIC HEAT PUMPS?

Thermoelectric heat pumps perform the same cooling function as freon-based vapor compression or absorption refrigerators. In all such units, thermal energy is extracted from a region, thereby reducing its temperature, then rejected to a "heat-sink" region of higher temperature. Vapor-cycle devices have moving mechanical parts and require a working fluid, while thermoelectric elements are totally solid state.

MELCOR's solid state heat pumps use thermocouples made of high performance crystalline semiconductor material. Passing a current through the heat pump generates a temperature differential across the thermocouples, with maximum ratings of 70°C and higher.

Solid state heat pumps have been known since the discovery of the Peltier effect in 1834. The devices became practical only recently, however, with the development of semiconductor thermocouple materials. MELCOR utilizes bismuth telluride, a quaternary alloy of bismuth, tellurium, selenium and antimony - doped and processed to yield oriented polycrystalline semiconductors with anisotropic thermoelectric properties. The couple, connected in series electrically and in parallel thermally, are integrated into modules. The modules are packaged between metallized ceramic plates to afford optimum electrical insulation and thermal conduction with high mechanical strength in compression. Typical MELCOR modules contain from 3 to 127 thermocouples; high technology applications for sophisticated instruments and communication systems require very small, low current modules, whereas low-cost, high capacity modules are in demand for a growing number of commercial applications. Modules can be mounted in parallel to increase the heat transfer effect or can be stacked in multistage cascades to achieve high differential temperatures.

SHOULD YOU USE THERMOELECTRIC HEAT PUMPS?

Thermoelectric devices are not the solution for every cooling problem. However, you should consider them when your system design criteria include such factors as high reliability, small size or capacity, low cost, low weight, intrinsic safety for hazardous electrical environments, and precise temperature control.

MODULES AND ASSEMBLIES AVAILABLE FROM MELCOR

A. FRIGICHIP® FC Series - sub miniature, low- and moderate capacity, low-current thermoelectric modules for use in maintaining critical temperatures in systems where determining factors are high reliability, limited space, and minimal power consumption.

B. FRIGICHIP® CP Series - low-cost, moderate- and high capacity, general-purpose modules for cooling equipment such as instrumentation, laboratory apparatus, consumer appliances, and for commercial and military applications.

C. MULTISTAGE (Cascade) Series - Standard and custom multistage (cascade) TEC's designed to meet requirements for large temperature differentials.

D. HEATPUMP Assemblies - packages including FRIGICHIPS and heat exchangers, designed and fabricated to customer specifications.

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THERMOELECTRIC HEAT PUMPS

Description

Thermoelectric (Peltier) heat pumps are capable of refrigerating a solid or fluid object. Unlike conventional vapor compressor systems, thermoelectric units (modules) are miniature devices. A typical module measures 1" x 1" x $^{3}/_{16}$" thick. Our smallest sub-miniature modules measure .16" x .16" x $^{3}/_{32}$" thick. These units are easily capable of reducing the temperature to well below freezing.

Competitive Advantages

It is possible to build thermoelectric systems in a space of less than 1 cubic inch. More typically, thermoelectric systems occupy about 20 to 30 in^3 of space. These systems are energized by a simple electrical power input.

In addition to the space and weight saving advantages, thermoelectrics offer the utmost in reliability due to its solid state construction. Another feature of importance is the ease with which a thermoelectric can be precisely temperature controlled, an important advantage for scientific, military and aerospace applications.

Thermoelectric Applications

Military/ Aerospace

Inertial Guidance Systems
Night Vision Equipment
"Smart" Munitions
Electronic Equipment Cooling
Cooled Personnel Garments
Parametric Amplifiers
Portable Refrigerators

Consumer Products

Recreational Vehicle Refrigerators
Mobile Home Refrigerators
Portable Picnic Coolers
Wine Coolers
Beer Keg Coolers
Motorcycle Helmet Refrigerators
Insulin Coolers (Portable)
Residential Water Coolers/Purifiers
Beverage Can Coolers

Laboratory and Scientific Equipment

Infrared Detectors
Photomultiplier Tube Housing Coolers
Laser Diode Coolers
Charge Coupled Device Coolers - (CCD)
Charge Induced Device Coolers - (CID)
Integrated Circuit Coolers
Vidicon Tube Coolers
Laboratory Cold Plates
Cold Chambers
Stir Coolers
Immersion Coolers
Ice Point Reference Baths
Microtome Stage Coolers
Electrophoresis Cell Coolers
Osmometers
Dewpoint Hygrometers
Air Pollution Control Analyzers
Oil Pour Point Apparatus
Constant Temperature Baths
Thermostat Calibrating Baths
Heat Density Measuring
Laser Collimators

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Industrial - Temperature Control

NEMA Enclosures
Microprocessors and PC's in Numerical Control and Robotics
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Fine Temperature Control
PC Computer Microprocessor Coolers

Restaurant Equipment

Cream Dispensers
Whipped Cream Dispensers
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Individual Portion Dispensers

Medical Instruments

Hypothermia Blankets
Blood analyzers
Tissue Preparation and Storage
Pharmaceutical Refrigerators - Portable and Stationary

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Hotel Room Refrigerators
Automobile Mini - Refrigerators
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APPLICATION NOTES FOR THERMOELECTRIC DEVICES

Since thermoelectric cooling systems are most often compared to conventional systems, perhaps the best way to show the differences in the in the two refrigeration methods is to describe the systems themselves.

A conventional cooling systems contains three fundamental parts - the evaporator, compressor and condenser. The evaporator or cold section is the part where the pressurized refrigerant is allowed to expand, boil and evaporate. During this change of state from liquid to gas, energy (heat) is absorbed. The compressor acts as the refrigerant pump and recompresses the gas to a liquid. The condenser expels the heat absorbed at the evaporator plus the heat produced during compression, into the environment or ambient.

A thermoelectric has analogous parts. At the cold junction, energy (heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element(p-type).

Thermoelectric Coolers are heat pumps, solid state heat pumps, heat pumps without moving parts, fluids or gasses. The basic laws of thermodynamics apply to these devices just as they do to conventional heat pumps, absorption refrigerators and other devices involving the transfer of heat energy.

An analogy often used to help comprehend a T.E. cooling system is that of a standard thermocouple used to measure temperature. Thermocouples of this type are made by connecting two wires of dissimilar metal, typically copper/constantan, in such a manner so that two junctions are formed. One junction is kept at some reference temperature, while the other is attached to the object being measured. The system is used when the circuit is opened at some point and the generated voltage is measured. Reversing this train of thought, imagine a pair of fixed junctions into which electrical energy is applied causing one junction to become cold while the other becomes hot.

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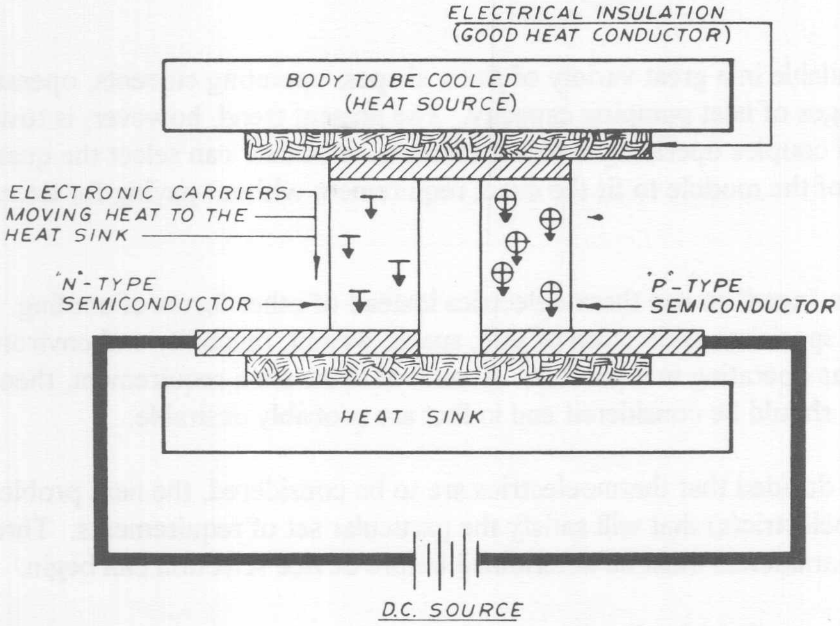
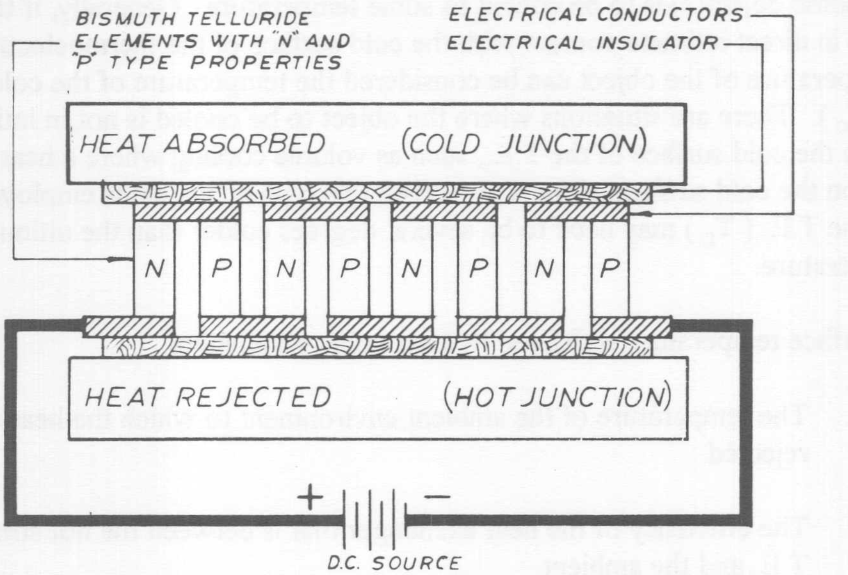
Fig. 1



CROSS SECTION OF TYPICAL THERMOELECTRIC COOLER

Thermoelectric cooling couples (Fig. 1) are made from two elements of semiconductor, primarily Bismuth Telluride, heavily doped to create either an excess (n-type) or deficiency (p-type) of electrons. Heat absorbed at the cold junction is pumped to the hot junction at a rate proportional to current passing through the circuit and the number of couples.

Fig. 2



TYPICAL MODULE ASSEMBLY — ELEMENTS ELECTRICALLY IN SERIES AND THERMALLY IN PARALLEL

In practical use, couples are combined in a module (Fig. 2) where they are connected electrically in series, and thermally in parallel. Normally a module is the smallest component commercially available.

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Modules are available in a great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The present trend, however, is toward a larger number of couples operating at lower currents. The user can select the quantity, size or capacity of the module to fit the exact requirement without paying for excess capacity.

There is usually a "need" to use thermoelectrics instead of other forms of cooling. The "need" may be a special consideration of size, space, weight, reliability and environmental conditions such as operating in a vacuum. If none of these are a requirement, then other forms of cooling should be considered and in fact are probably desirable.

Once it has been decided that thermoelectrics are to be considered, the next problem is to select the thermoelectric(s) that will satisfy the particular set of requirements. Three specific system parameters must be determined before device selection can begin.

These are: T_c Cold Surface Temperature

T_h Hot Surface temperature

Q_c The amount of heat to be absorbed at the Cold Surface of the T.E.

In most cases the cold surface temperature is usually given as part of the problem - that is to say that some object(s) is to be cooled to some temperature. Generally, if the object to be cooled is in direct intimate contact with the cold surface of the thermoelectric, the desired temperature of the object can be considered the temperature of the cold surface of the T.E. (T_c). There are situations where the object to be cooled is not in intimate contact with the cold surface of the T.E., such as volume cooling where a heat exchanger is required on the cold surface of the T.E. When this type of system is employed the cold surface of the T.E. (T_c) may need to be several degrees colder than the ultimate desired object temperature.

The Hot Surface temperature is defined by two major parameters:

1) The temperature of the ambient environment to which the heat is being rejected.

2) The efficiency of the heat exchanger that is between the hot surface of the T.E. and the ambient.

These two temperatures (T_c & T_h) and the difference between them (ΔT) are very important parameters and therefore must be accurately determined if the design is to operate as desired. Figure 3 represents a typical temperature profile across a thermoelectric system.

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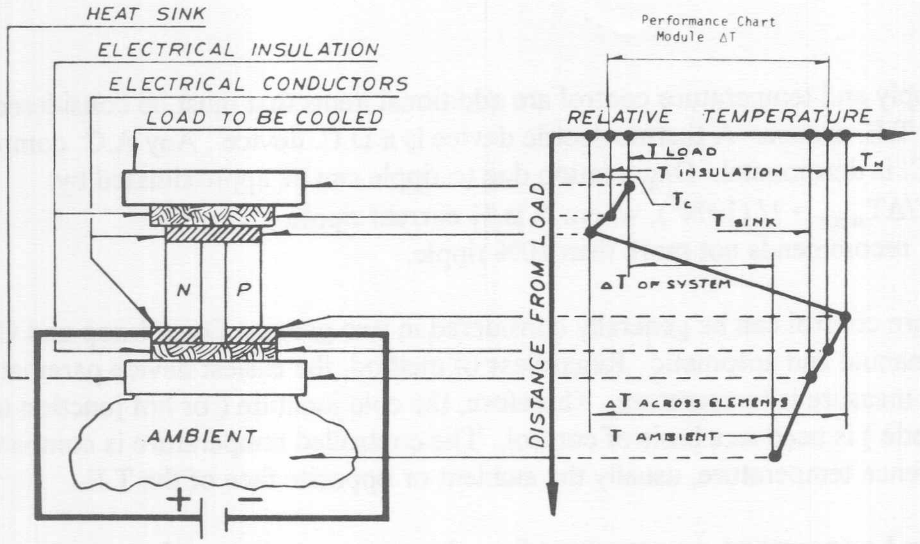
Fig. 3



TYPICAL TEMPERATURE RELATIONSHIP
IN A THERMOELECTRIC COOLER

The third and often most difficult parameter to accurately quantify is the amount of heat to be removed or absorbed by the cold surface of the T.E. All thermal loads to the T.E. must be considered. These thermal loads include, but are not limited to, the active or I^2R heat load from electronic devices and conduction through any object in contact with both the cold surface and any warmer temperature (i.e. electrical leads, insulation, air or gas surrounding objects, mechanical fasteners, etc.). In some cases radiant heat effects must also be considered.

Single stage thermoelectric devices are capable of producing a "no load" temperature differential of approximately 67°C. Temperature differentials greater than this can be achieved by stacking one thermoelectric on top of another. This practice is often referred to as Cascading. The design of a cascaded device is much more complex than that of a single stage device, and is beyond the scope of these notes. Should a cascaded device be required, design assistance can be provided by MELCOR personnel.

Once the three basic parameters have been quantified, the selection process for a particular module or group of modules may begin. Some common heat transfer equations are attached for help in quantifying Q_c & T_h.

There are many different modules or sets of modules that could be used for any specific application. One addition criteria that is often used to pick the "best" module(s) is Coefficient of Performance (C.O.P.). C.O.P. is defined as the heat absorbed at the cold junction, divided by the input power ($Q_c \div Q_{in}$). The maximum C.O.P. case has the advantages of minimum input power and therefore, minimum total heat to be rejected by the heat exchanger ($Q_h = Q_c + Q_{in}$). These advantages come at a cost, which in this case is the additional or larger T.E. device required to operate at C.O.P. maximum. It naturally follows that the major advantage of the minimum C.O.P. case is the lowest initial cost.

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Power supply and temperature control are additional items that must be considered for a successful T.E. system. A thermoelectric device is a D.C. device. Any A.C. component on the D.C. is detrimental. Degradation due to ripple can be approximated by:

$\Delta T/\Delta T_{max} = 1/\,(1+N^2)$, where N is % current ripple.

MELCOR recommends not more than 10% ripple.

Temperature control can be generally considered in two groups: Open Loop and Closed Loop, or manual and automatic. Regardless of method, the easiest device parameter to detect and measure is temperature. Therefore, the cold junction (or hot junction in heating mode) is used as a basis of control. The controlled temperature is compared to some reference temperature, usually the ambient or opposite face of the T.E.

In the Open Loop method, an operator adjust the power supply to reduce the error to zero. The Closed Loop accomplishes this task electronically. The various control circuits are too numerous, complex and constantly being upgraded to try to discuss in this text. There are several manufacturers of control circuits and systems that are better equipped to give expert counsel in this specific area. Suffice it to say that the degree of control, and consequent cost, varies considerably with the application.

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PARAMETERS REQUIRED FOR DEVICE SELECTION

There are certain minimum specifications that anyone must answer before the selection of a T.E. device can begin. Specifically there are three parameters that are required. Two of these parameters are the temperatures that define the gradient across the T.E. device. The third parameter is the total amount of heat that must be pumped by the device.

The gradient across the T.E. device (Actual ΔT) is not the same as the apparent ΔT (System ΔT). The difference between these two ΔT's is often ignored, which results in an under designed system. The magnitude of the difference in ΔT's, is largely dependant on the type of heat exchangers that are utilized on either the hot or cold sides of the system.

Unfortunately, there are no "Hard Rules", that will accurately define these differences. Typical allowances for the hot side of a system are:

(1.) finned forced air: 10 to 15°C

(2.) free convection: 20 to 40 °C

(3.) liquid exchangers: 2 to 5 °C

Since the heat flux densities on the cold side of the system are considerably lower than those on the hot side, an allowance of about 50% of the hot side figures (Assuming similar types of heat exchangers) can be used. It is good practice, to check the outputs of the selection process to reassure that the heat sink design parameters are reasonable.

The third parameter that must be identified for the selection process, is the total heat to be pumped by the T.E. device. This is often the most difficult number to estimate! To reduce the temperature of an object, heat must be removed from it, faster than heat enters it. There are generally two broad classifications of the heat that must be removed from the device. The first is the real, sensible or "active" heat load. This is the load that is representative of what wants to be done. This load could be the I^2R load of an electrical component, the load of dehumidifying air, or the load of cooling objects. The "other" kind of load is often referred to as the parasitic load. This is the load due to the fact that the object is cooler than the surrounding environment. This load can be comprised of conduction and convection of the surrounding gas, "leak" through insulation, conduction through wires, condensation of water, and in some cases formation of ice. Regardless of the source of these parasitic loads they must not be ignored.

There are other things that may be very important to a specific application. Things such as physical dimensions, input power limitations or cost. Even though these are important, they are only secondary.

MELCOR's approach to thermoelectric device selection/recommendation utilizes a computer aided design program which computes an optimized thermoelectric design for the given operating hot side temperature, desired cold side temperature, and the total heat load to be pumped over the Actual ΔT.

We have attached a "check list" to assist you in defining your application's existing conditions. If you should require any further assistance please do not hesitate contacting one of our engineers.

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THERMOELECTRIC (T.E.) MULTISTAGE (CASCADED) DEVICES

A multistage thermoelectric device should be used only where a single stage device does not fill the need. Figure 1, depicts ΔT, vs C.O.P. MAX, vs. Number of stages. C.O.P. is defined as the amount of heat absorbed (in thermal watts heat pumped) at a the cold side of the device, divided by the input power (in electrical watts). This figure should help identify when to consider cascades since it portrays the effective ΔT range of each cascade. A two stage cascade should be thought of, somewhere between a ΔT of 40°C, where the C.O.P. lines of the 1 and 2 stage devices begin to diverge, and 65°C, where a single stage device reaches its maximum ΔT, and also, heat pumping "shutoff", $Q_c = 0$. Similar decisions must be made as to the number of stages to be considered at larger ΔT's. The two important factors again are ΔT and C.O.P.

There is another very significant factor that must always be considered and that is the cost. Usually, as the number of stages increase, so does the cost. Certain applications require a trade-off between C.O.P. and cost.

As with any other T.E. system, to begin the selection process requires the definition of at least three parameters.

These are: T_c ⇒ Cold side temperature
T_h ⇒ Hot side temperature
Q_c ⇒ The amount of heat to be removed (absorbed) by the cooled surface of the T.E.

Once ΔT (T_h-T_c) and the heat load have been defined, utilization of Figure 1 will yield the number of stages that may be required. Knowing C.O.P. and Q_c, input power can also be estimated. The values listed in Figure 1 are theoretical maximums. Any device that is actually manufactured will rarely achieve these maximums, but should closely approach this value.

MELCOR does not offer a line of 'Standard Cascades' as there are no 'Standard' applications. Each need for a cascade is unique, so to should be the device selected to fill the need. MELCOR has developed a computer aided design system to help select a device. The three parameters listed above are used as inputs to the programs. Other variable such as physical size, and operating voltage or current can, within limits, be used to make the final selection. Over 40,000 different cascades can be assembled utilizing available ceramic patterns. This allows near custom design, at near 'standard' prices. When the three parameters have been defined, please contact MELCOR for assistance in cascade selection.

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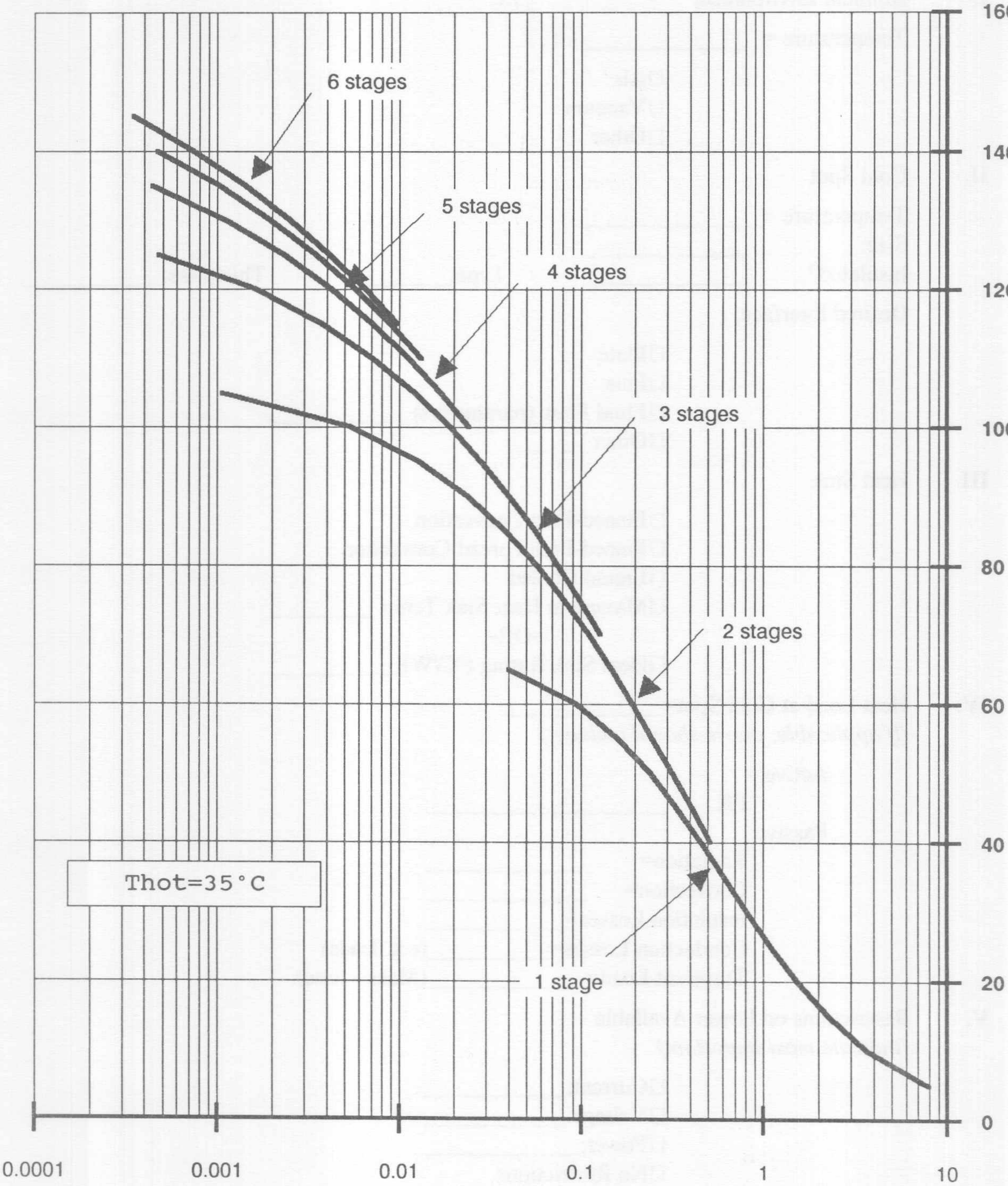
Figure 1: C.O.P. MAX as a function of Delta T and # of stages



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DESIGN/SELECTION CHECK LIST

The information requested below is vital to the design/selection of a thermoelectric device to achieve your desired performance.

Please attempt to define as many of your application's existing conditions and limiting factors as possible. *(Please indicate units on all parameters)*

I. Ambient Environment

Temperature = ____________

- ☐Air
- ☐Vacuum
- ☐Other

II. Cold Spot

Temperature =____________

Size: ____________

Insulated? ____________ Type:________ Thickness:____________

Desired Interface:

- ☐Plate
- ☐Fins
- ☐Fluid Flow (parameters)____________
- ☐Other_______

III. Heat Sink

- ☐Finned-Free Convection
- ☐Finned-Free Forced Convection
- ☐Liquid Cooled
- ☐Maximum Heat Sink Temp._________

-OR-

- ☐Heat Sink Rating (°C/W)___________

IV. Heat Load at Cold Spot=____________

(if applicable, above should include:)

Active:

I^2R ____________________

Passive:

Radiation= ____________

Convection= ____________

Insulation Losses=____________

Conduction Losses=__________(e.g. leads)

Transient Load=____________(Mass - time)

V. Restrictions on Power Available

(indicate most important)

- ☐Current:____________
- ☐Voltage:____________
- ☐Power:____________
- ☐No Restrictions

VI. Restrictions on Size:______________

VII. To ensure the most effective response, please provide a rough, dimensioned sketch of the application, indicating the anticipated physical configuration and thermoelectric module placement.

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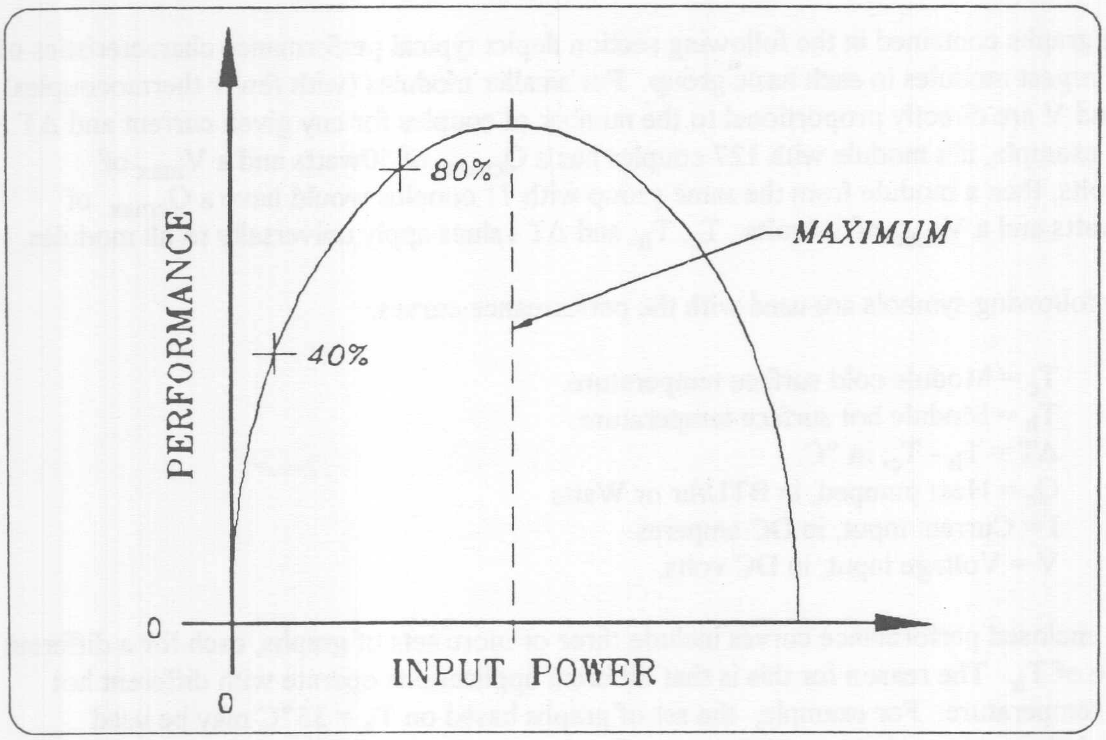
TYPICAL DEVICE PERFORMANCE



When PERFORMANCE vs. INPUT POWER is plotted for any thermoelectric device, the resultant curve will appear as in the figure above ; an inverted parabola. Performance can be ΔT (T_h - T_c), heat pumped at the cold side (Q_c), or as in most cases, a combination of these two parameters. Input power can be current (I), voltage (V) or the product of IV.

When we refer to the ΔT_{max} or Qc_{max}, we are referring to that point where the curve peaks. The same is true when referring to either I_{max} or V_{max}. Since operating at or very near the peak is relatively inefficient, most devices are operated somewhere between 40% and 80% of Input Power MAX.

As stated, devices are normally operated on the near-linear, upward sloping portion of the curve. When automatic or closed loop temperature control is being used, current or voltage limits should be set below the MAX intercepts.

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HOW TO USE THE PERFORMANCE CURVES

The graphs contained in the following section depict typical performance characteristics of the largest modules in each basic group. For smaller modules (with fewer thermocouples), Q and V are directly proportional to the number of couples for any given current and ΔT For example, if a module with 127 couples has a Q_{cmax}. of 50watts and a V_{max} of 15volts, then a module from the same group with 71 couples would have a Q_{cmax} of 28watts and a V_{max} of 8.4volts. T_c, T_h, and ΔT values apply universally to all modules.

The following symbols are used with the performance curves:

T_c = Module cold surface temperature.
T_h = Module hot surface temperature.
$\Delta T = T_h - T_c$, in °C.
Q_c = Heat pumped, in BTU/hr or Watts.
I = Current input, in DC amperes.
V = Voltage input, in DC volts.

The enclosed performance curves include three or more sets of graphs, each for a different value of T_h. The reason for this is that different applications operate with different hot side temperature. For example, the set of graphs based on T_h = 35°C may be used directly in an air-cooled heat sink applications where the ambient air temperatures are 23°C to 29°C. But, if your particular application operates with a different T_h due to different ambient temperatures or for any other reason, then a graph based on a different T_c may be better suited for the your particular thermal assembly.

With T_h, T_c, and Q_c known, the corresponding value of I is determined from the ΔT vs. Q_c graphs. Then, knowing $\Delta T$and I, the value of V can be determined from the ΔT vs. V graphs.

Linear interpolation can be used when finding thermal parameters for applications having T_h values between the ones shown on the graphs.

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EXAMPLE:

It is found that a cold plate requires 30 watts of heat pumping to maintain a temperature of 0°C in an ambient temperature of 25°C. It is also found that this design requires a T_c of -5°C, and a T_h of 35°C to allow for temperature gradients across the cold plate and the heat sink. Assuming that 10 amps are available, try using the performance curves for the CP2-31-06L.

1) Using the center section (T_h = 35°C), find the 40°C on the top x axis (ΔT *(40)* = T_h *(35)* -T_c *(-5)*).

2) Come down to the 10 amp line and look across to the y axis (Input Voltage). This tells you that the CP2-31-06L module will require an input voltage of approximately 3 volts.

3) Continuing down to the next 10 amp line, and looking over to the y axis (Q_c -watts heat pumped), tells you that the module will pump 10 watts under these conditions: (T_h = 35°C, T_c = -5°C, I = 10 amps, V = 3 volts)

Therefore, to pump 30 watts would require using three CP2-31-06L placed thermally in parallel with each module having 10 amps of input current.

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HEAT TRANSFER FORMULAE

NOTE: Due to the relatively complex nature of heat transfer, results gained from application of these formulae, while useful, must be treated as approximations only. Design safety margins should be considered before final selection of any device.

1) Heat gained or lost through the walls of an insulated container:

$$\boxed{Q = \frac{A \times \Delta T \times K}{\Delta X}}$$

Where: Q = Heat (*W*)
A = External surface area of container (m^2)
ΔT = Temp. difference (inside vs. outside of container) (°K)
K = Thermal conductivity of insulation (*W/ m - °K*)
ΔX = Insulation thickness (*m*)

2) Time required to change the temperature of an object:

$$\boxed{t = \frac{m \times C_p \times \Delta T}{Q}}$$

Where: t = Time interval (*seconds*)
C_p = Specific heat of material (*J/kg - °K*)
m = weight of the object (*kg*)
ΔT = Temperature change of object (°K)
Q = Heat added or removed (*W*)

NOTE: It should be remembered that thermoelectric devices do not add or remove heat at a constant rate when ΔT is changing. An approximation for average Q is:

$$\boxed{\frac{Q(@\Delta T_{max}) + Q(@\Delta T_{min})}{2}}$$

3) Heat transferred to or from a surface by convection:

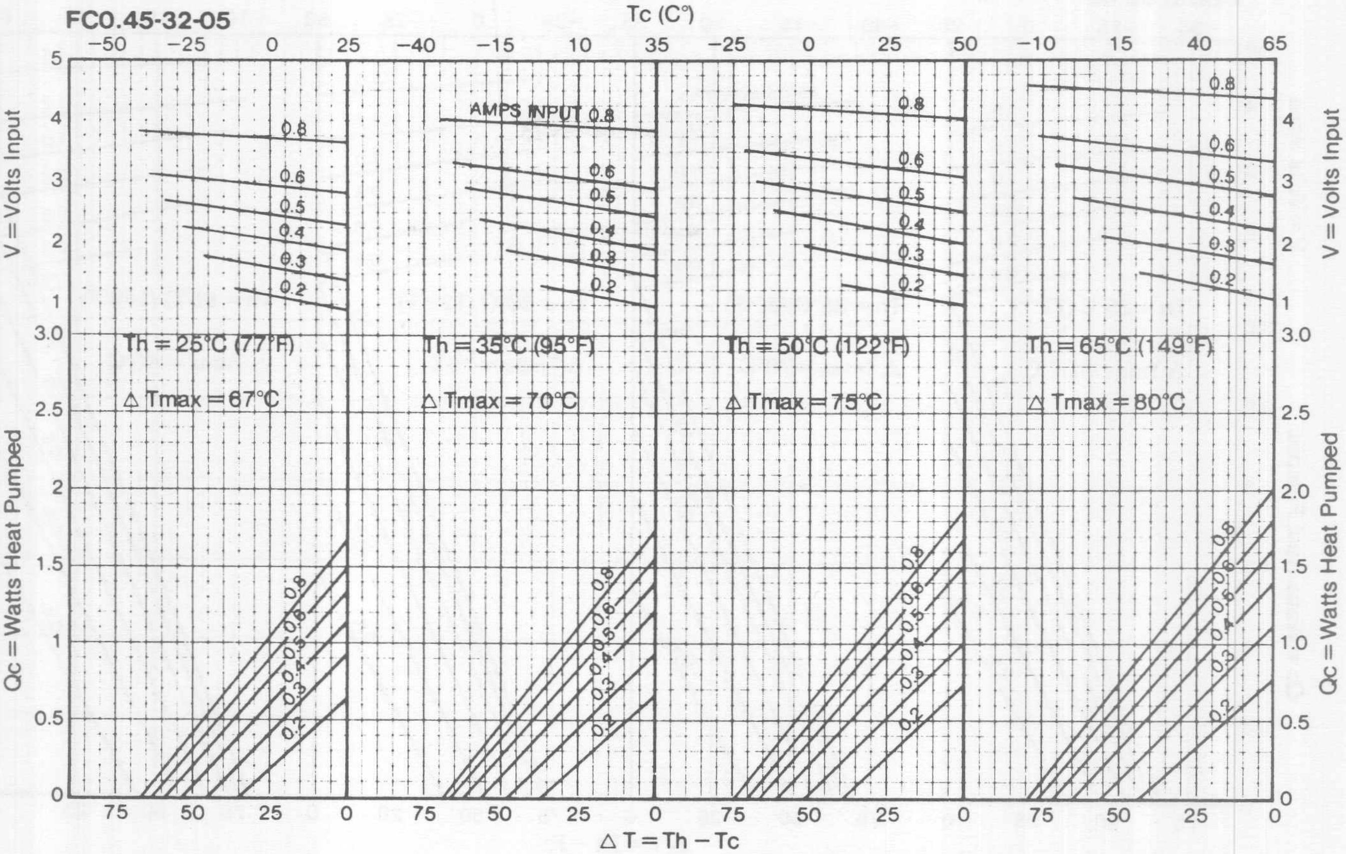
$$\boxed{Q = h \times A \times \Delta T}$$

Where: Q = Heat (W)
h = Heat transfer coefficient (*W/m^2 - °K*)
(1 to 30 = "Free" convection - gases, 10 to 100 = Forced convection - gases)
A = Exposed surface area (m^2)
ΔT = Surface Temp. - Ambient (°K)

Conversions:

Thermal Conductivity	1 BTU/hr-ft °F	=	1.73 W/m-°K
	1 W/m-°K	=	0.578 BTU/hr-ft-°F
Power (heat-flow rate)	1 W	=	3.412 BTU/hr
	1 BTU/hr	=	0.293 W
Area	1 ft^2	=	0.093 m^2
	1 m^2	=	10.76 ft^2
Length	1 ft	=	0.305 m
	1 m	=	3.28 ft
Specific Heat	1 BTU/lb-°F	=	4184 J/kg-°K
	1 J/kg-°K	=	2.39 x 10^{-4} BTU/lb-°F
Heat Transfer Coefficient	1 BTU/hr-ft^2-°F	=	5.677 W/m^2-°K
	1 W/m^2-°K	=	0.176 BTU/hr-ft^2-°F
Mass	1 lb	=	0.4536 kg
	1 kg	=	2.205 lb

FC0.45-32-05



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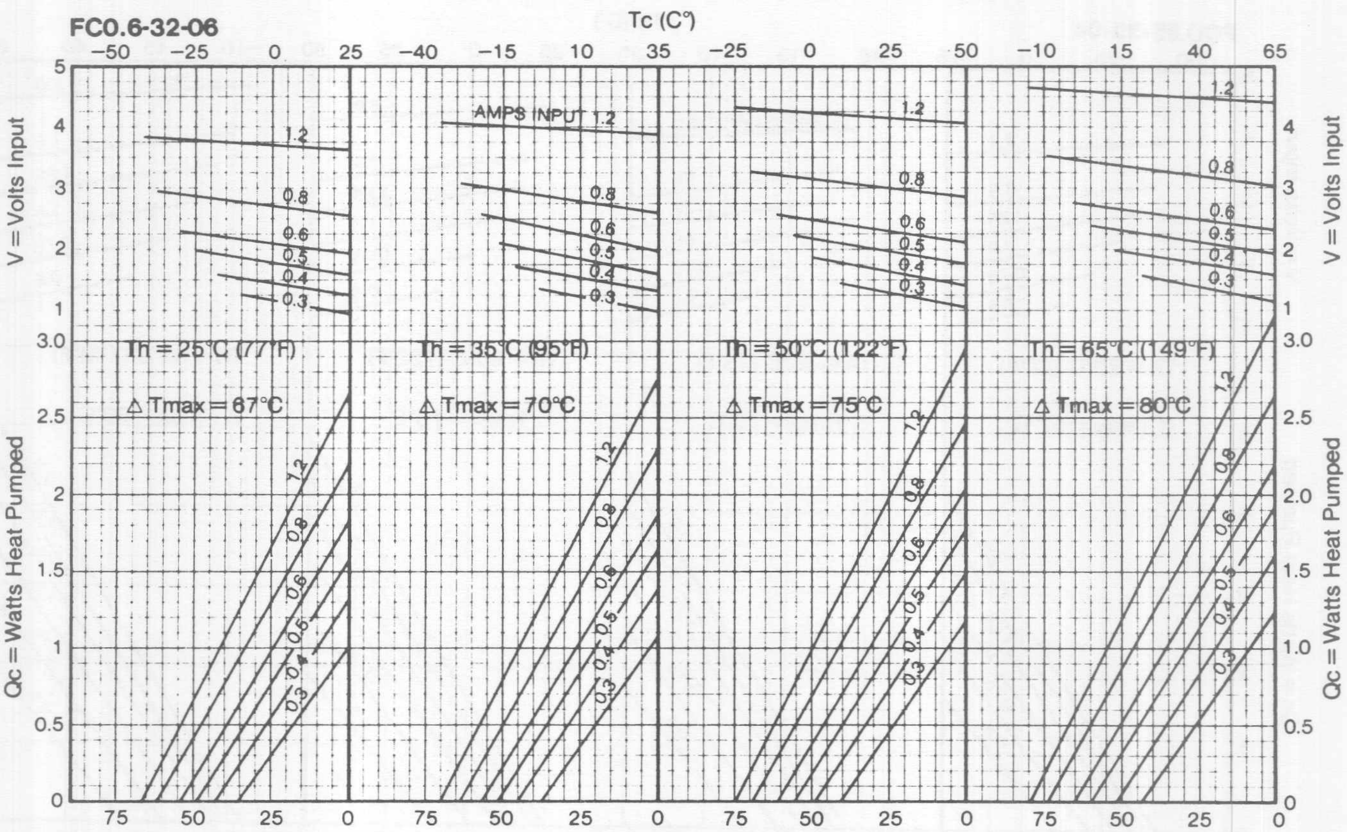

Th = Hot Face Temperature Tc = Cold Face Temperature

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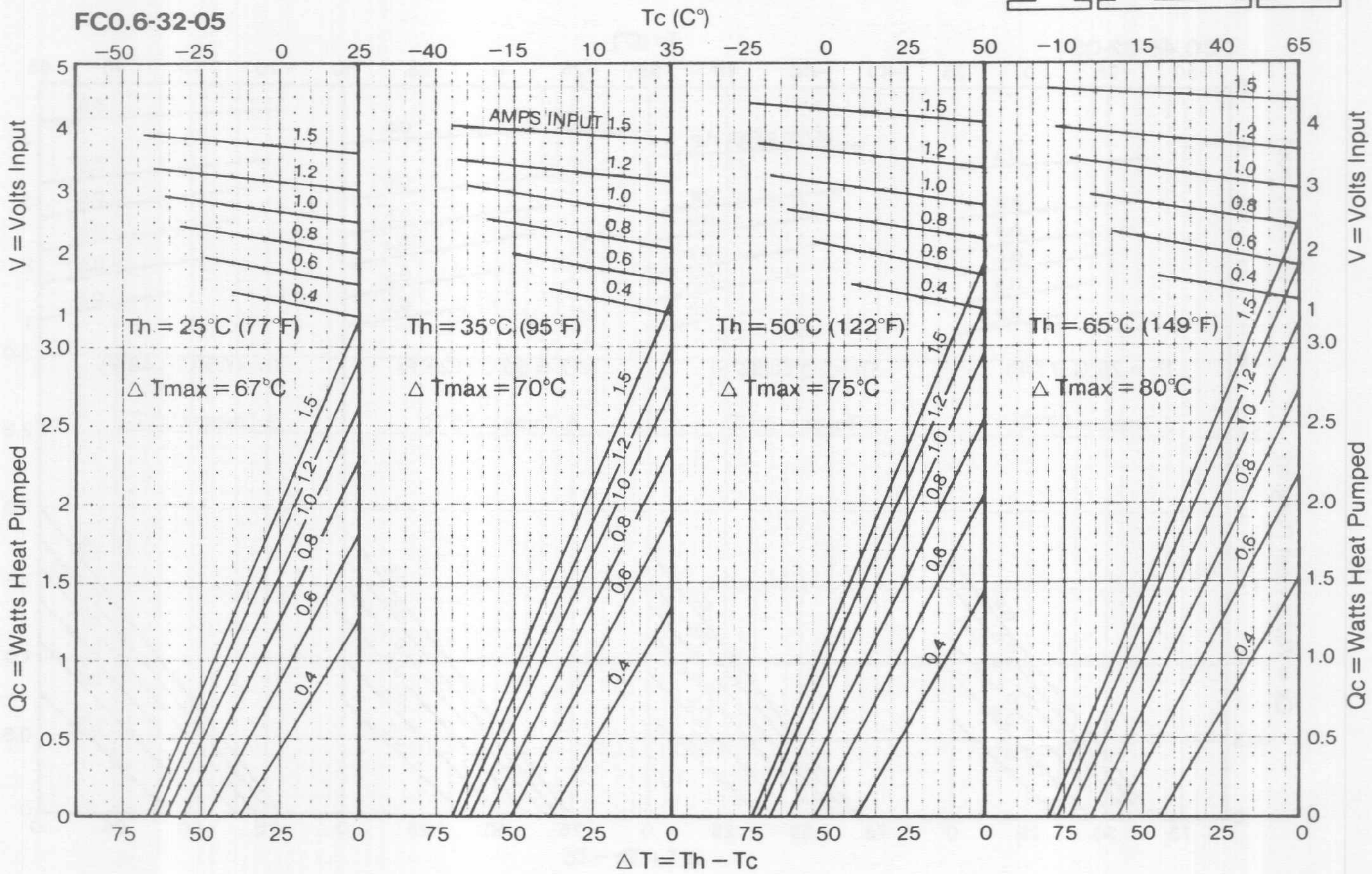

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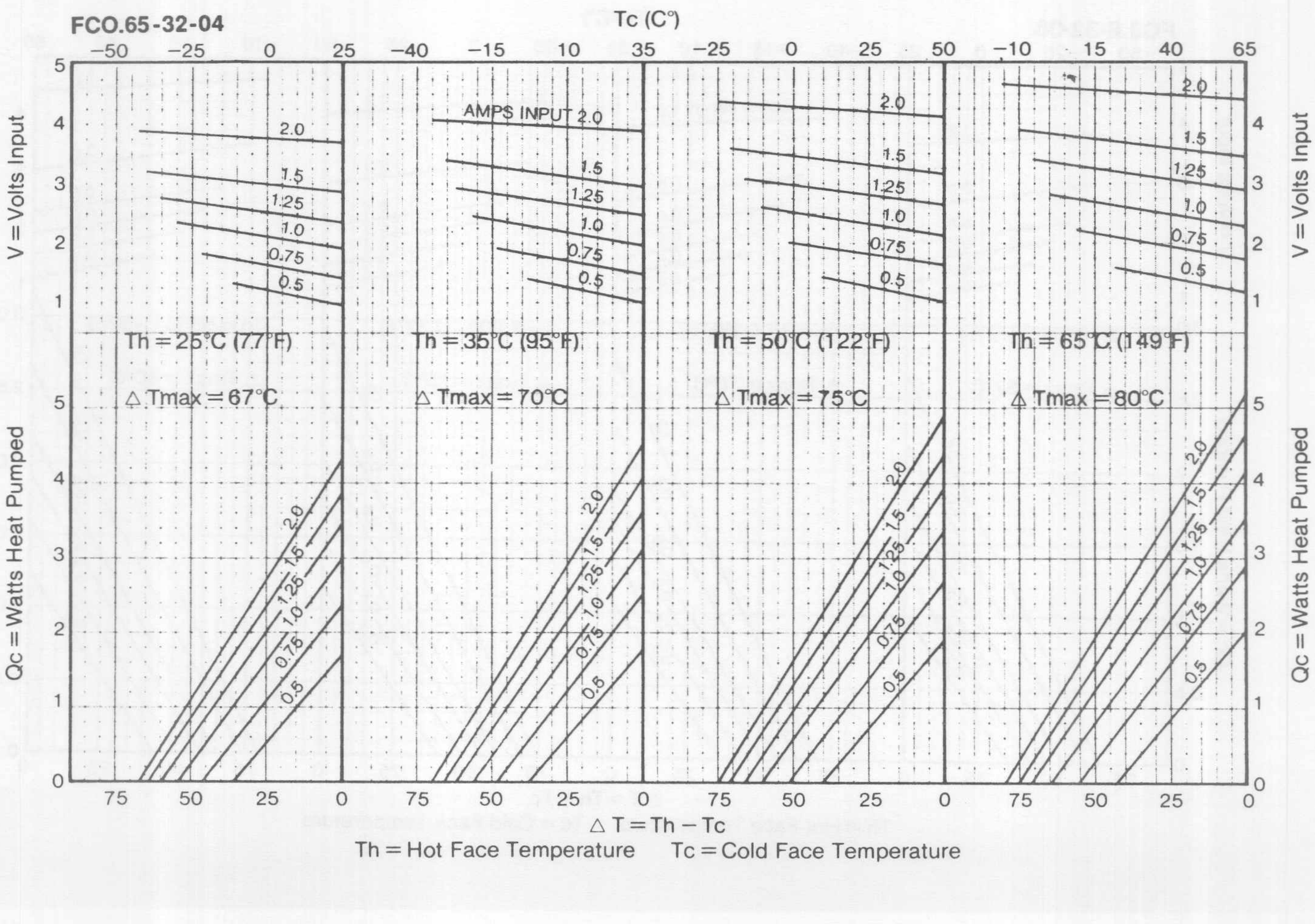
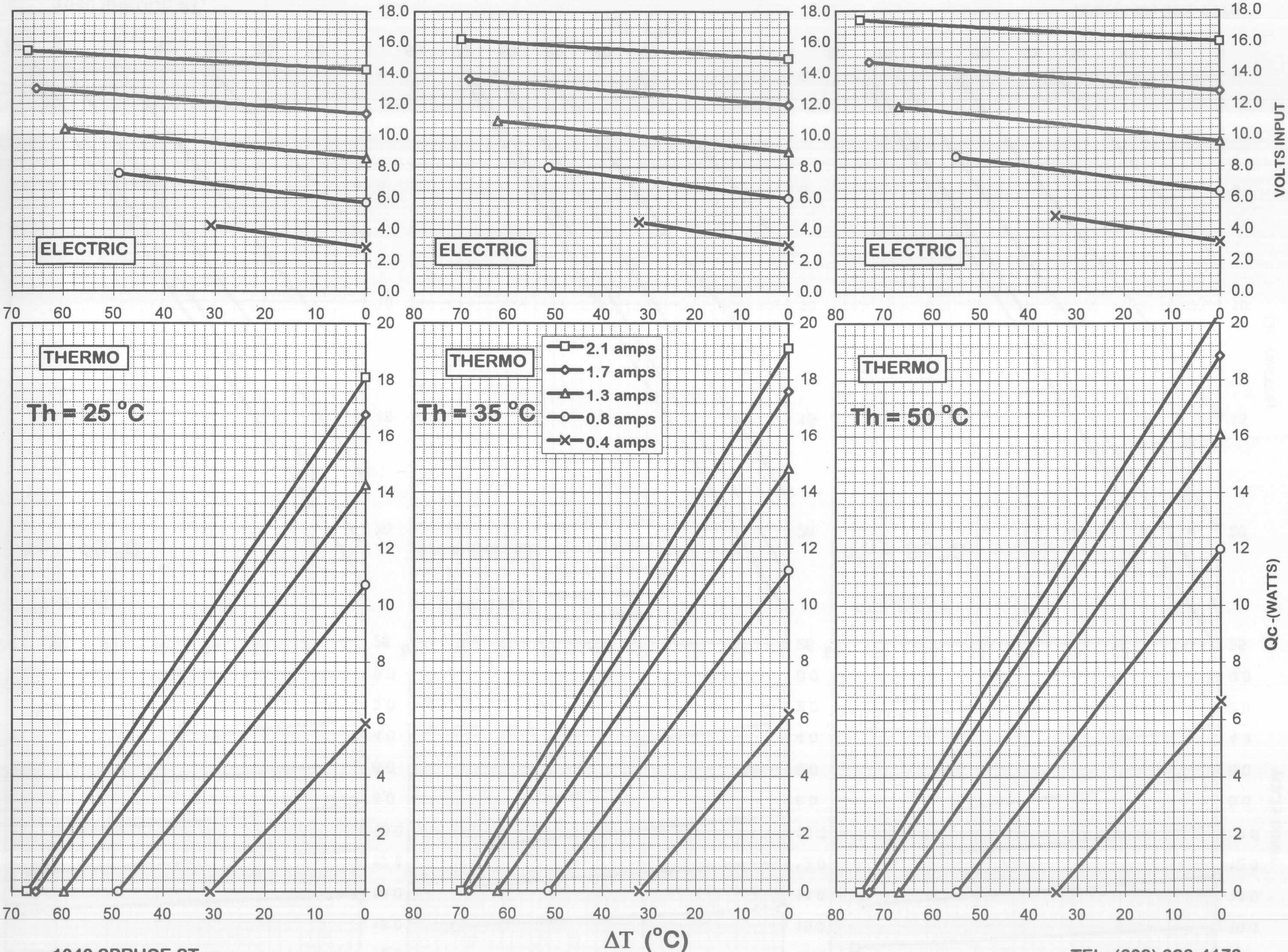


Th = Hot Face Temperature   Tc = Cold Face Temperature

PERFORMANCE GRAPH

CP 0.8-127-06 L



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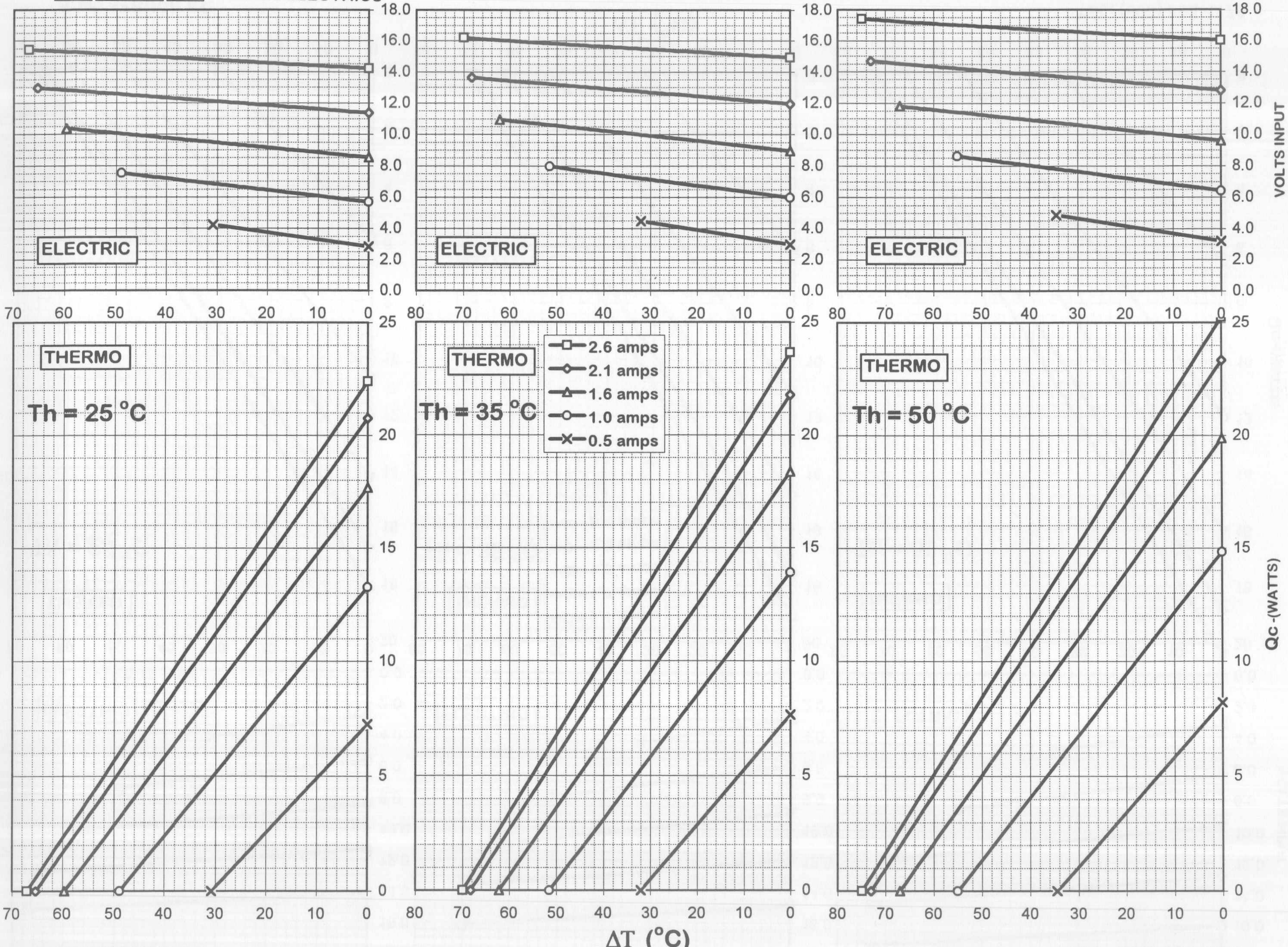
MELCOR THERMOELECTRICS

PERFORMANCE GRAPH

CP 0.8-127-05 L



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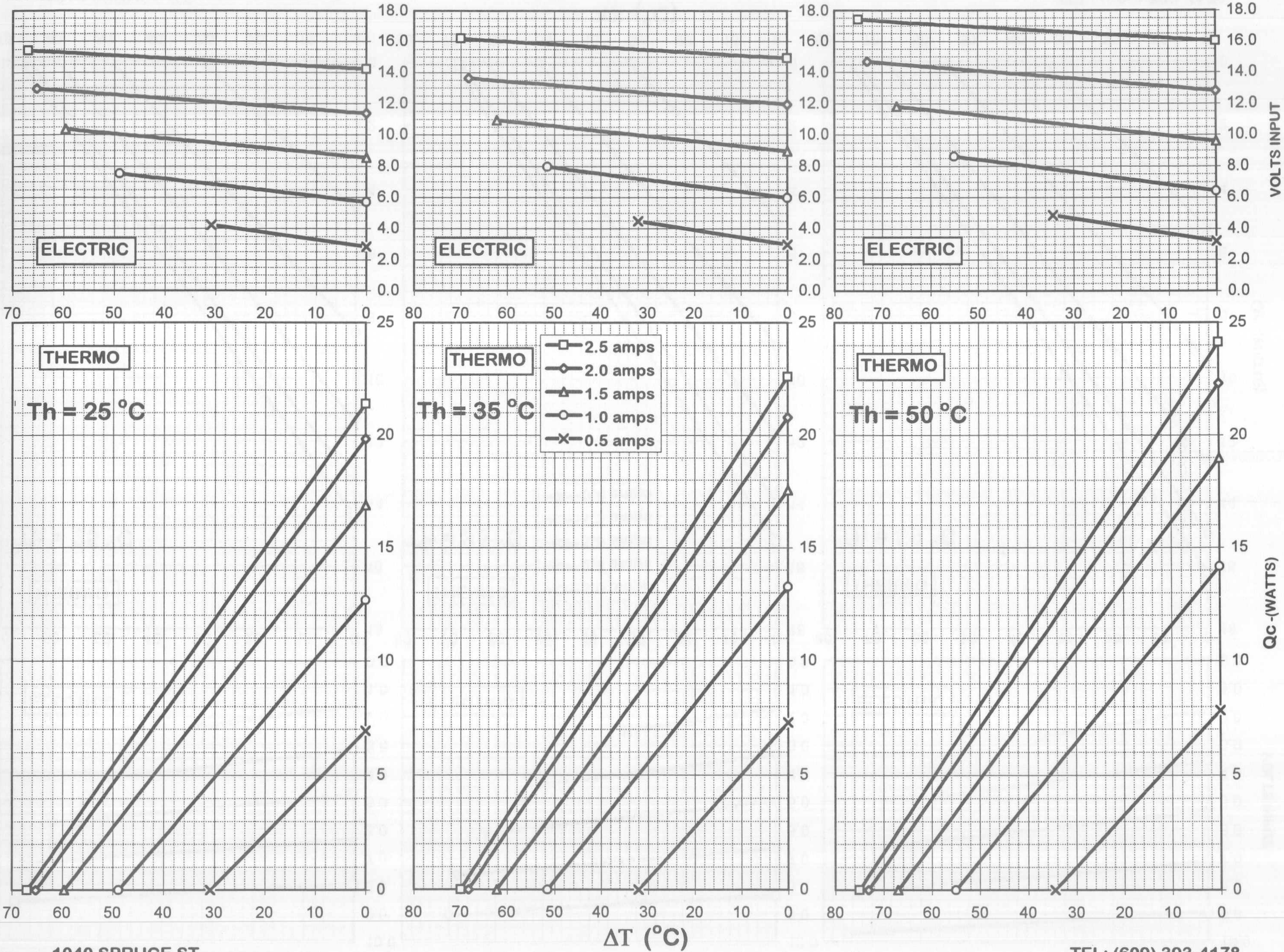
CP 1.0-127-08 L



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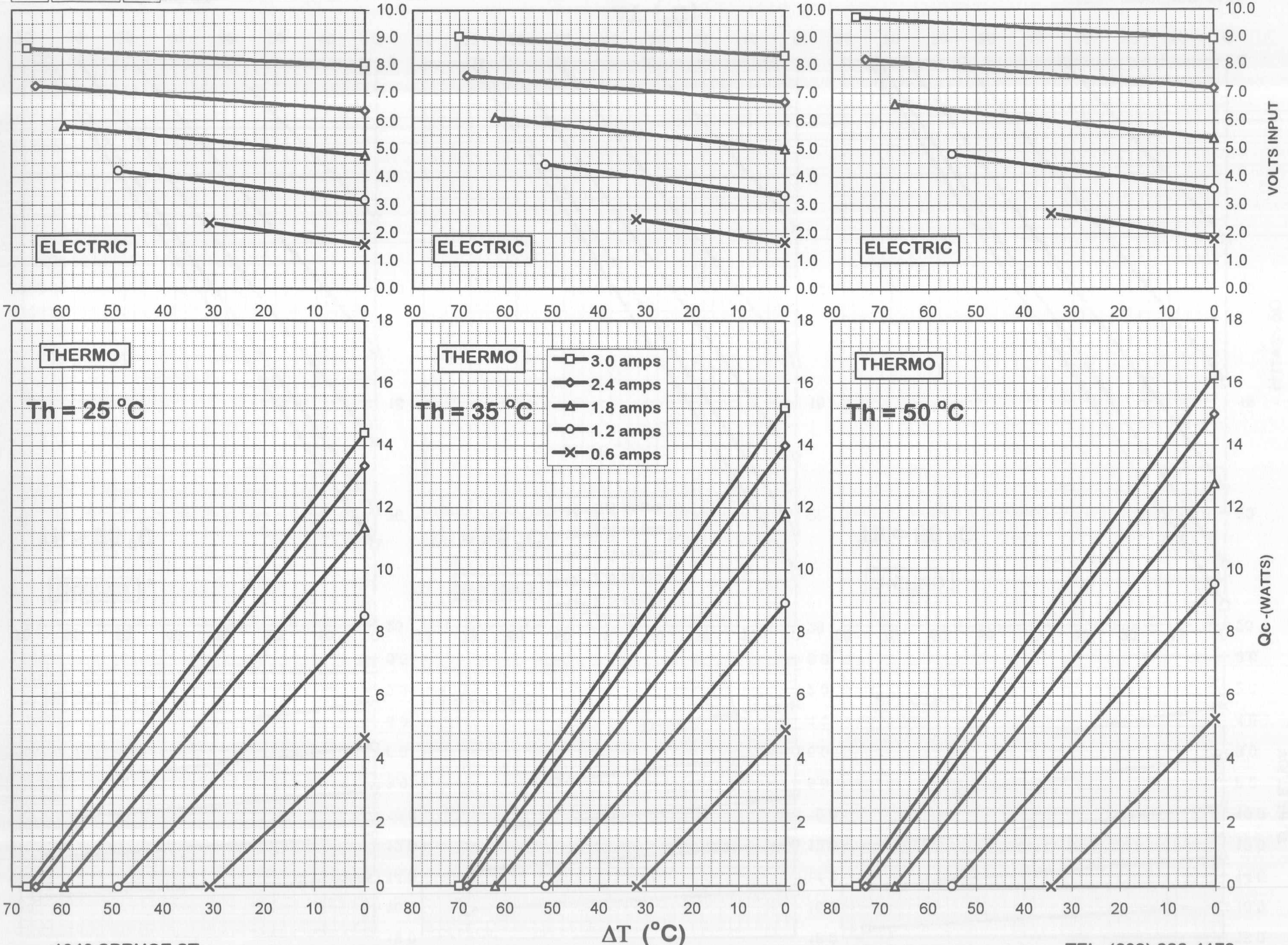
PERFORMANCE GRAPH

CP 1.0-71-06 L



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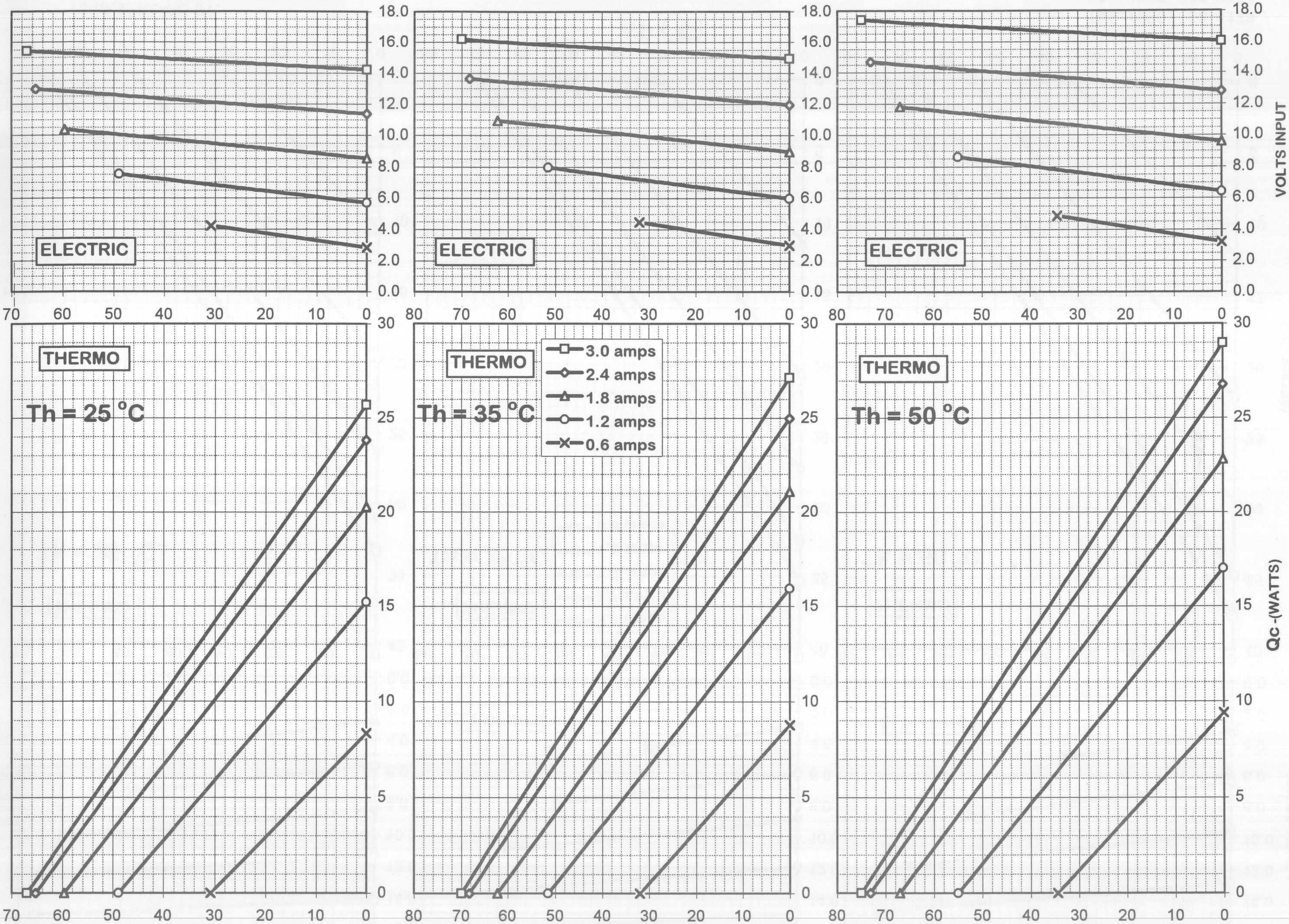
PERFORMANCE GRAPH

CP 1.0-127-06 L



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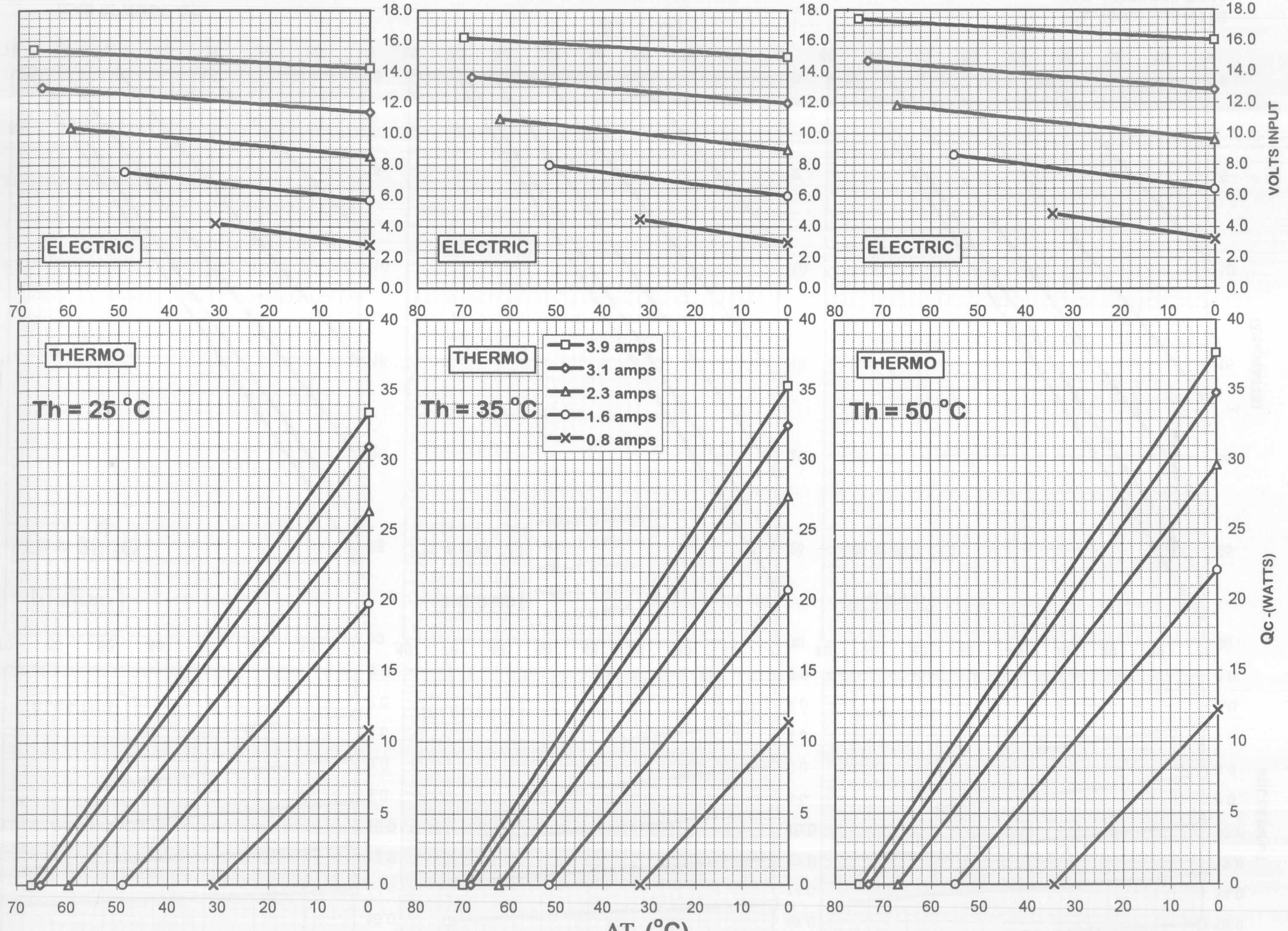
PERFORMANCE GRAPH

CP 1.0-127-05 L



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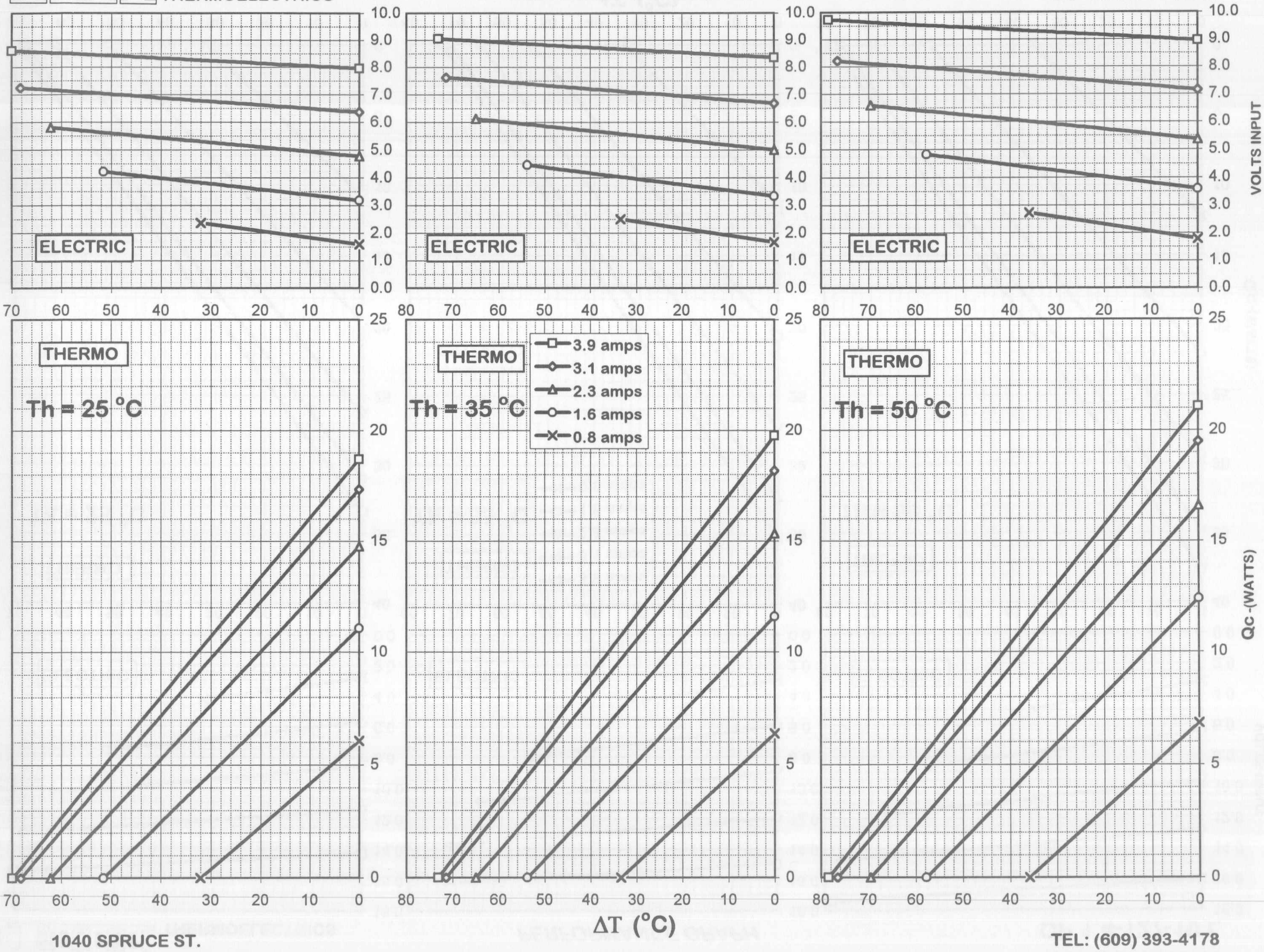
PERFORMANCE GRAPH

CP 1.4-71-10 L



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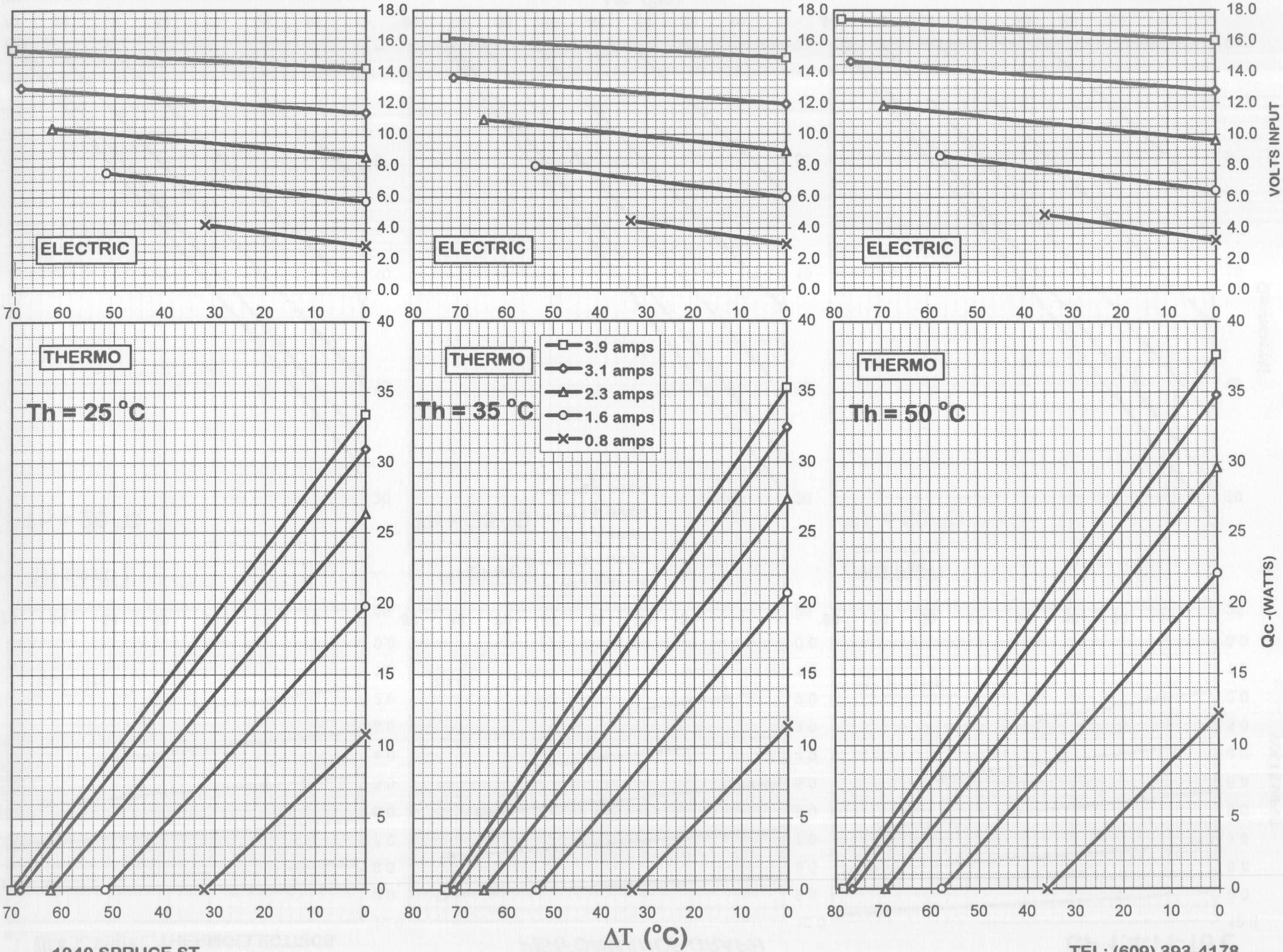
CP 1.4-127-10 L



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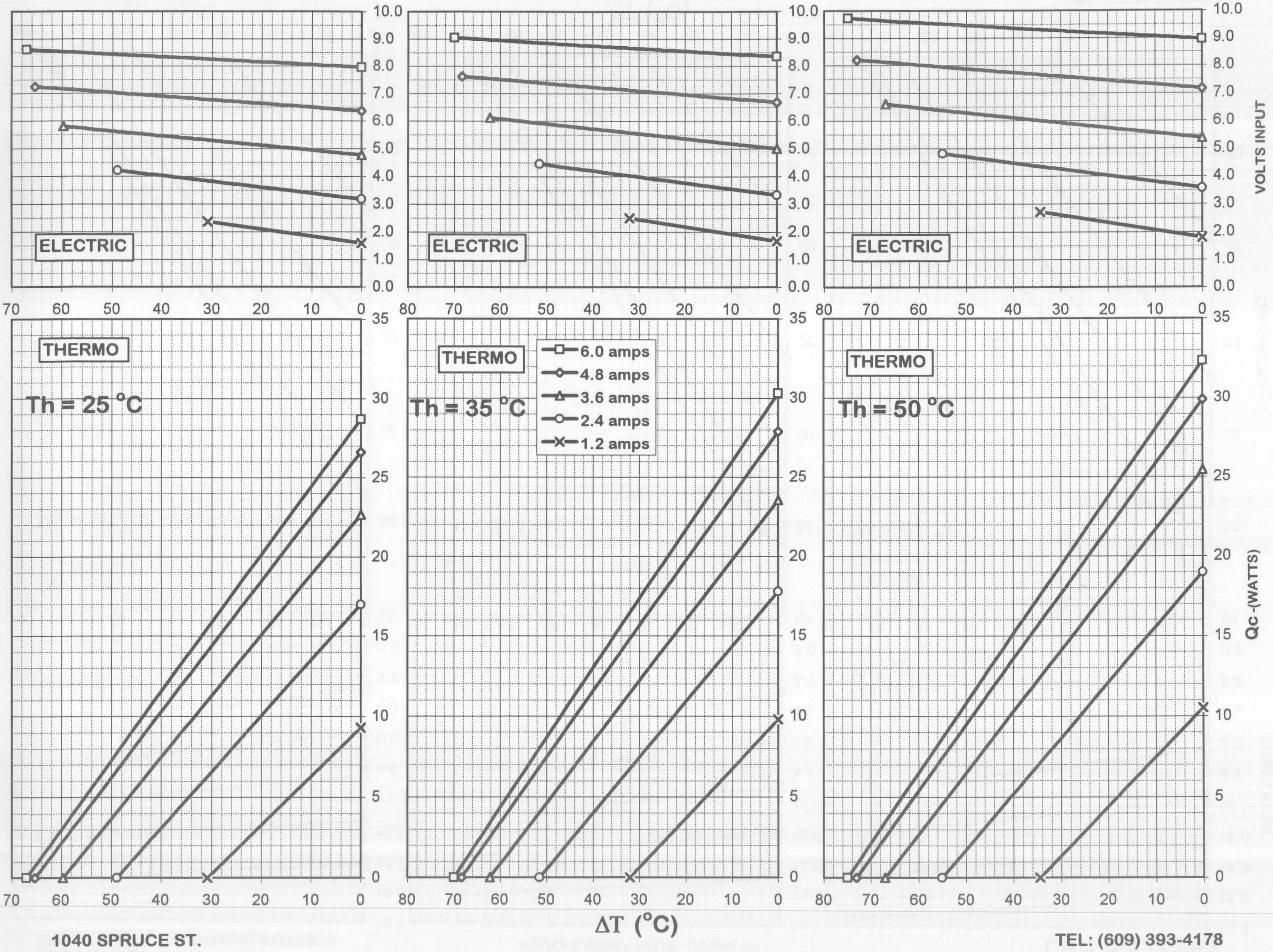
MELCOR THERMOELECTRICS | *PERFORMANCE GRAPH* | **CP 1.4-71-06 L**



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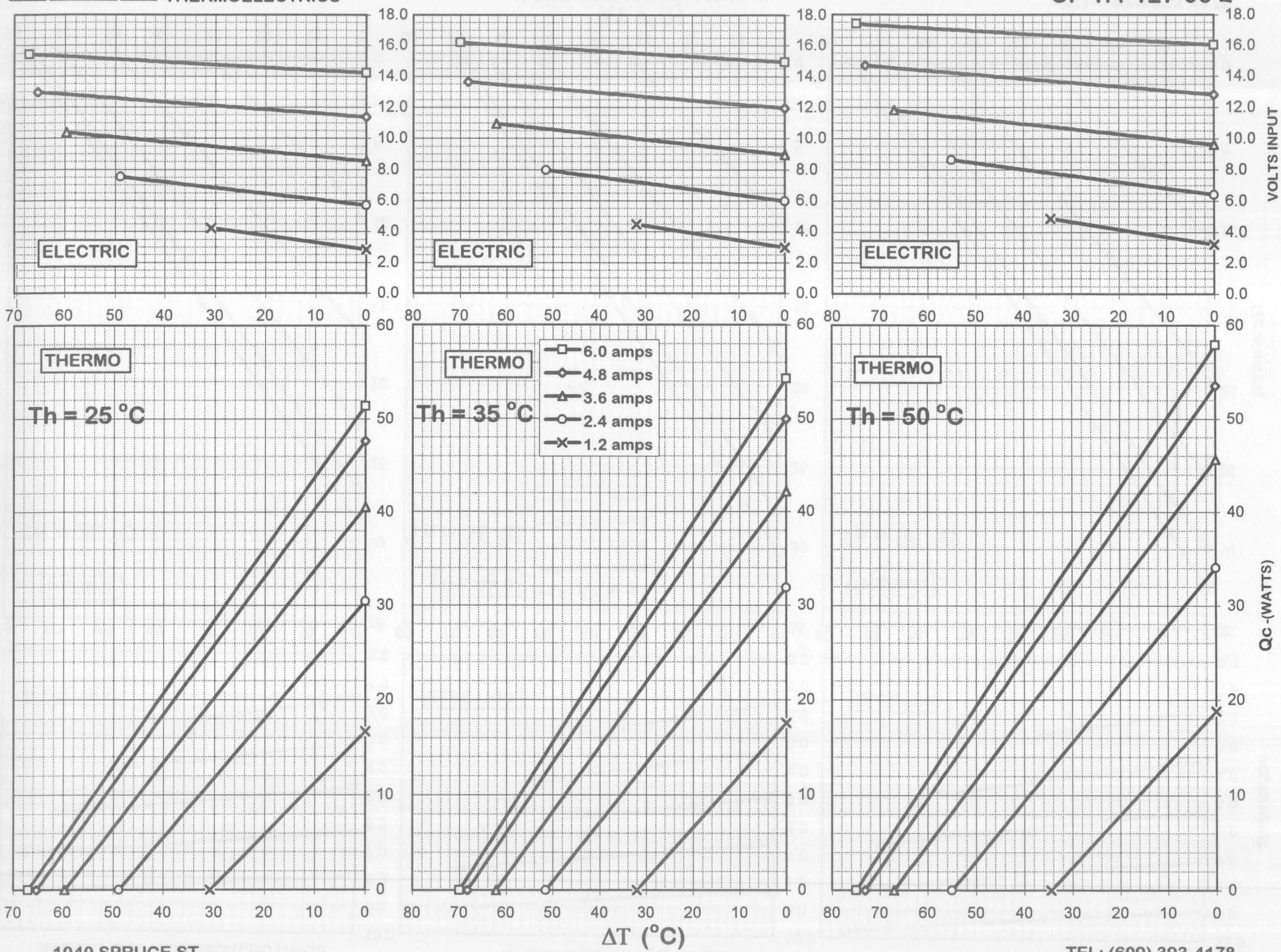
PERFORMANCE GRAPH

CP 1.4-127-06 L



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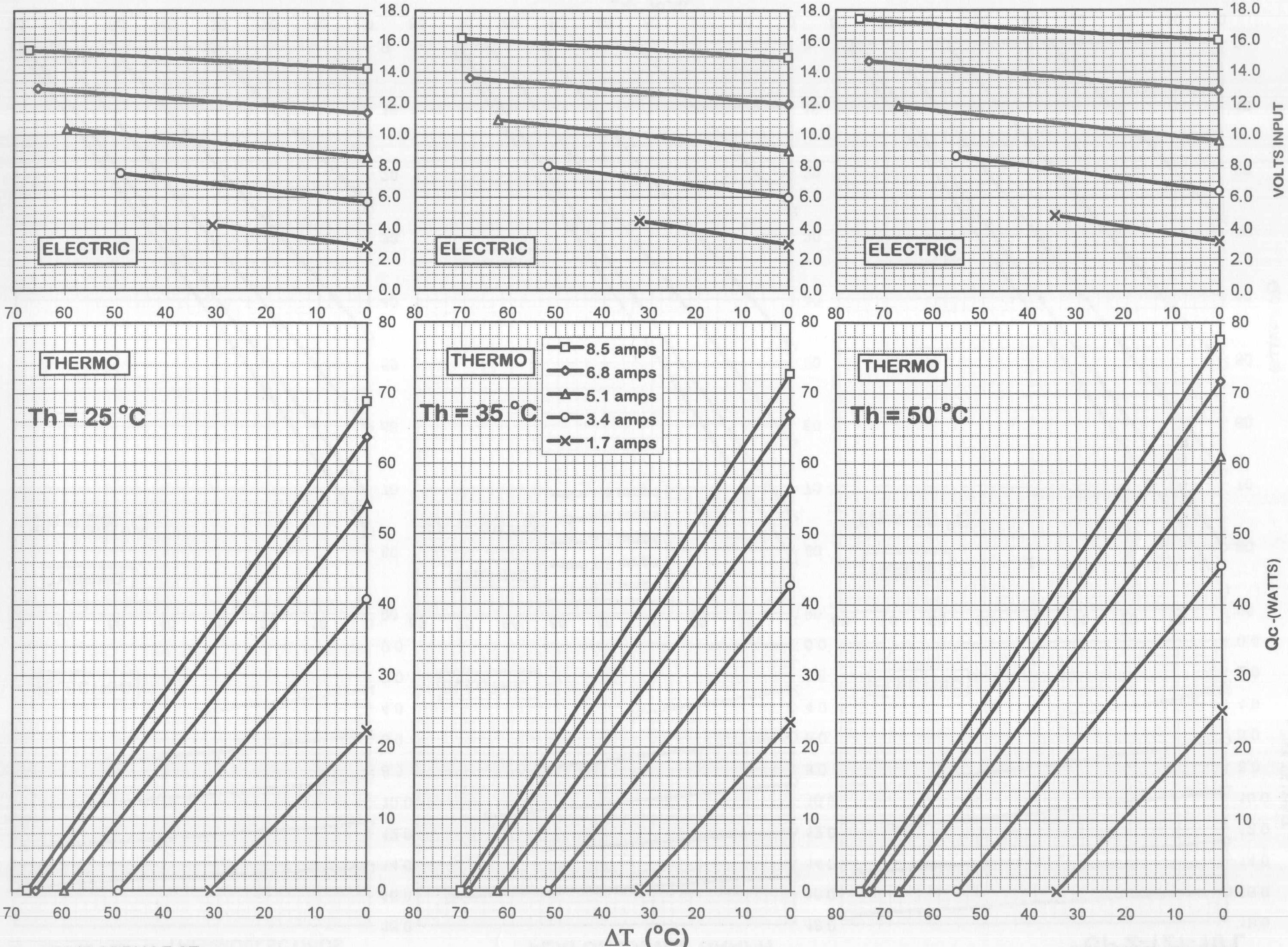
CP 1.4-127-045 L



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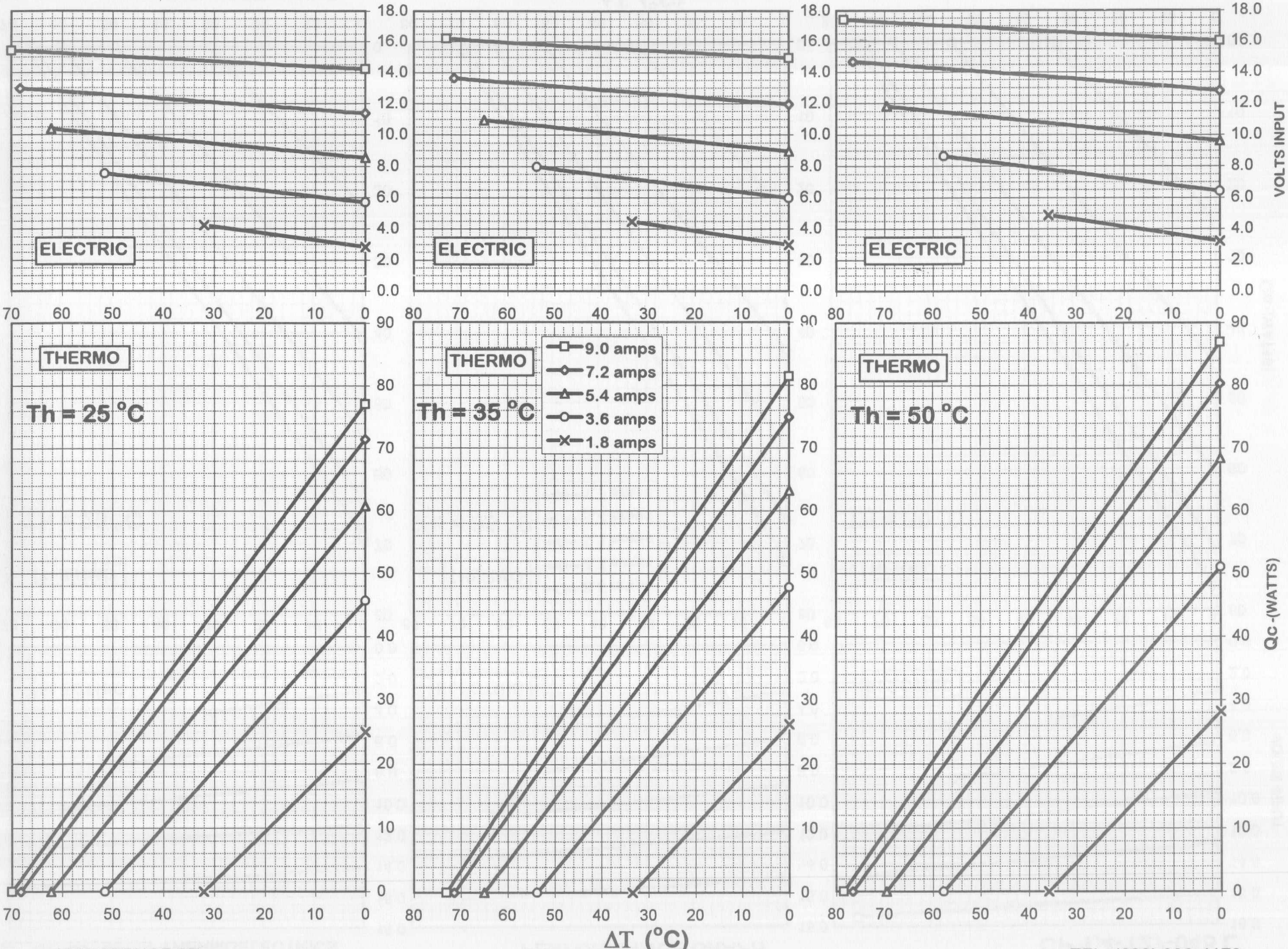
PERFORMANCE GRAPH

CP 2-127-10 L



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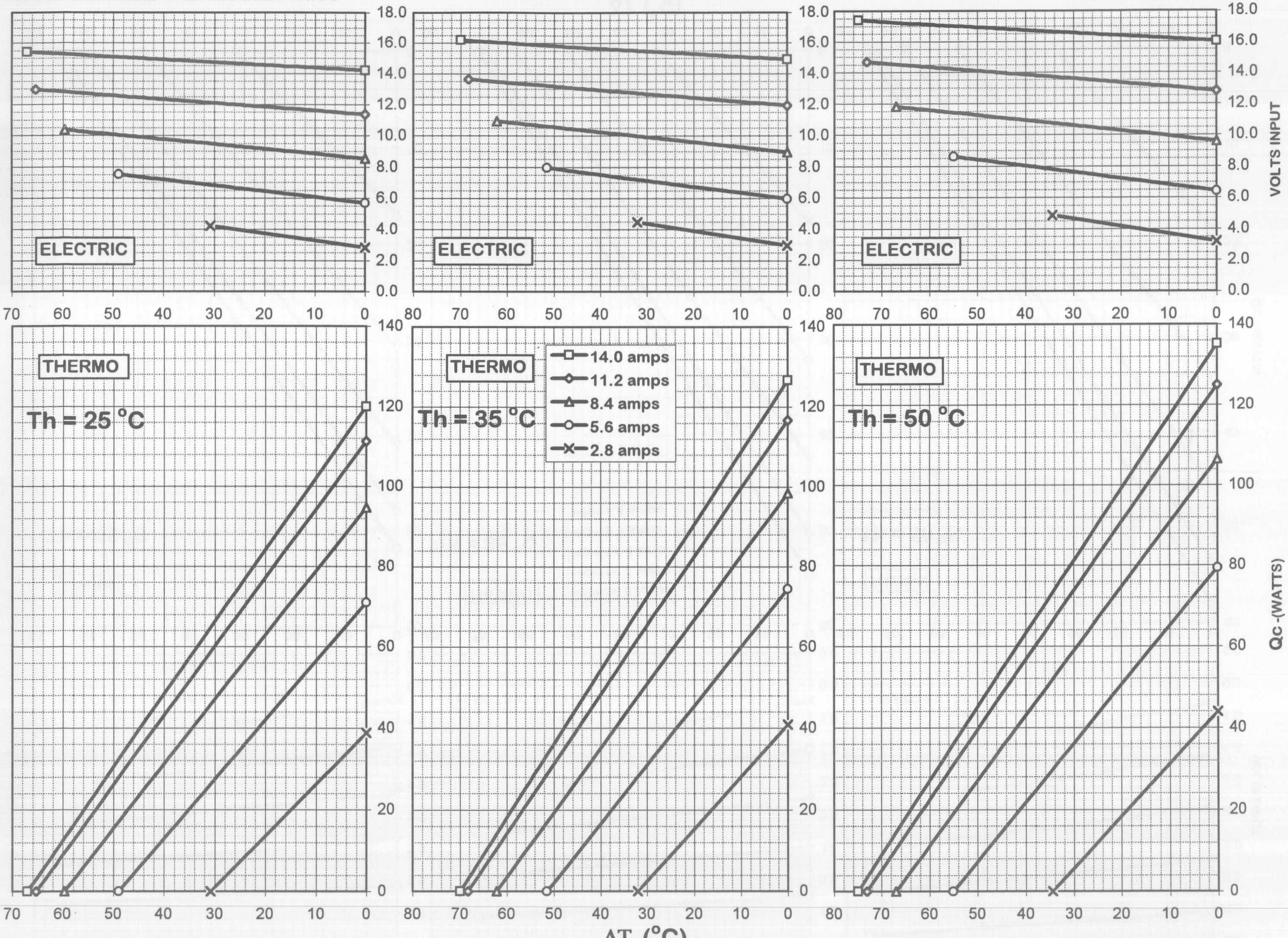
THERMOELECTRICS

PERFORMANCE GRAPH

CP 2-127-06 L



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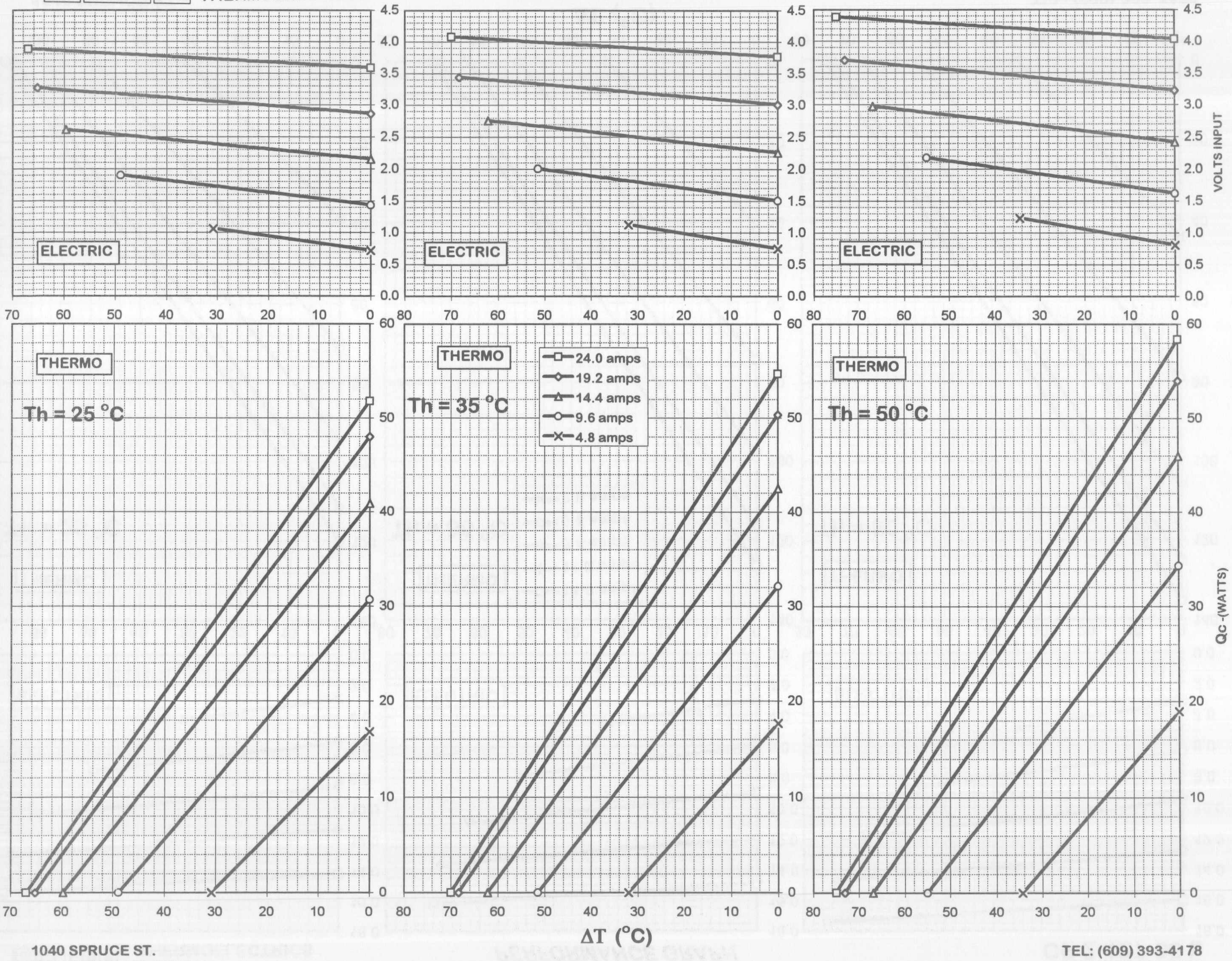
PERFORMANCE GRAPH

CP 2.8-32-06 L



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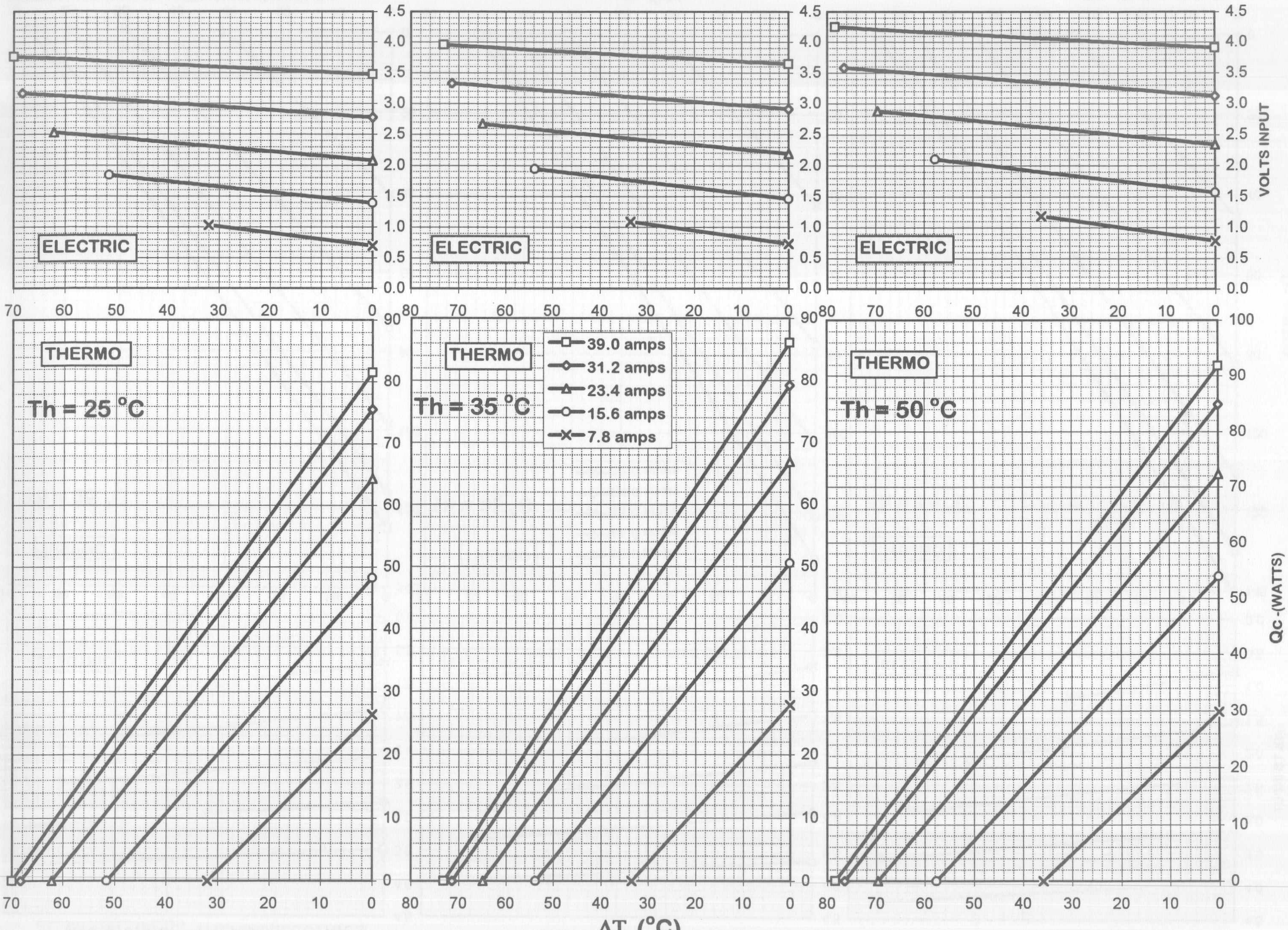

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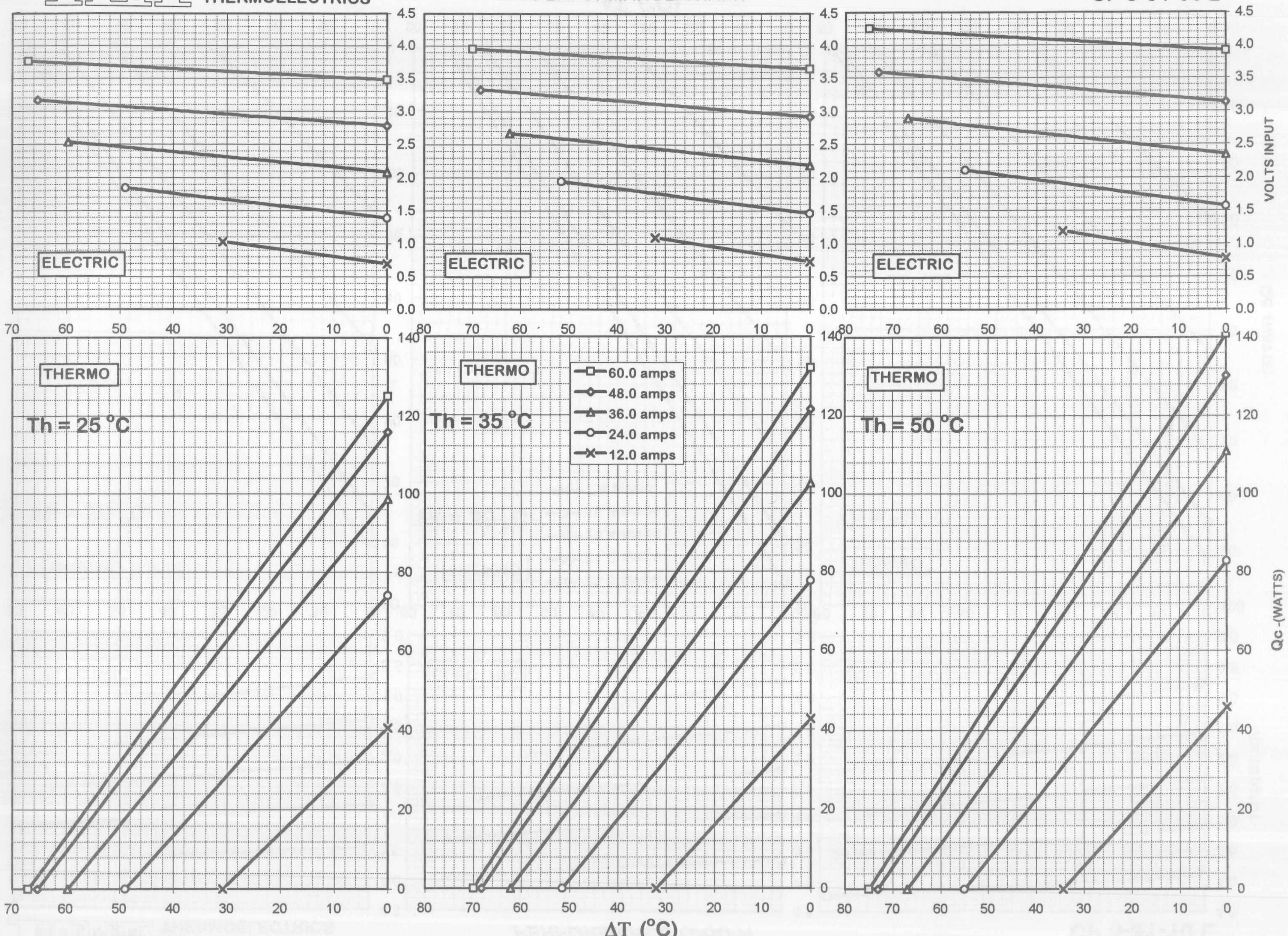
PERFORMANCE GRAPH

CP 5-31-06 L



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ASSEMBLY TIPS

The techniques used in the assembly of a thermoelectric (T.E.) system can be as important as the selection of the proper device. It is imperative to keep in mind the purpose of the assembly -- namely to move heat. Generally a T.E. device, in the cooling mode, moves heat from an object to ambient. All of the mechanical interfaces between the objects to be cooled and ambient are also thermal interfaces. Similarly all thermal interfaces tend to inhibit the flow of heat or add thermal resistance. Again, when considering assembly techniques every reasonable effort should be made to minimize thermal resistance.

Mechanical tolerances for heat exchangers surfaces should not exceed 0.001 in/in with a maximum of 0.003" Total Indicated Reading. Should there be a need to use more than one module between common plates the height variation between modules should not exceed 0.001" (request tolerance lapped modules when ordering). Most T.E. assemblies utilize one or more "thermal grease" interfaces. The grease thickness should be held to 0.001 plus/minus .0005" (a printers ink roller works well for this). When these types of tolerances are to be held a certain level of cleanliness must be maintained. Dirt, grit and grime should be minimized, this is very important when "grease" joints are utilized due to their affinity for these types of contaminants.

Once the T.E. modules have been assembled between the heat exchangers, some form of insulation/seal should be provided between the exchangers surrounding the modules. Since the area within the module, (i.e. the element matrix), is an open DC circuit and a temperature gradient is often present, gas flow, which may contain water that could condense should be minimized. Typically, a T.E. module is about 0.2" thick, any insulation that can be provided will minimize heat leak. The presence of the insulation/seal also offers some protection from physical damage.

The insulation/seal is often most easily provided by inserting sections of closed cell polyurethane foam about the cavity and sealing with either an RTV type substance or for more physical integrity an epoxy coat can be used. Whatever form is used, it should provide the protection outlined above. It is often desirable to provide strain relief for the input leads, not only to protect the leads themselves, but to help maintain the integrity of the seal about the modules

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ASSEMBLY TIPS (continued)

We have included miscellaneous drawings to help show some details of assembly tips.

Drawing No. M90250 shows the details of the recommended construction of a typical assembly. The use of a "spacer block" yields maximum heat transfer, while separating the hottest and coldest parts of the system, by the maximum amount of insulation. The "spacer blocks" are used on the cold side of the system due to the lower heat flux density.

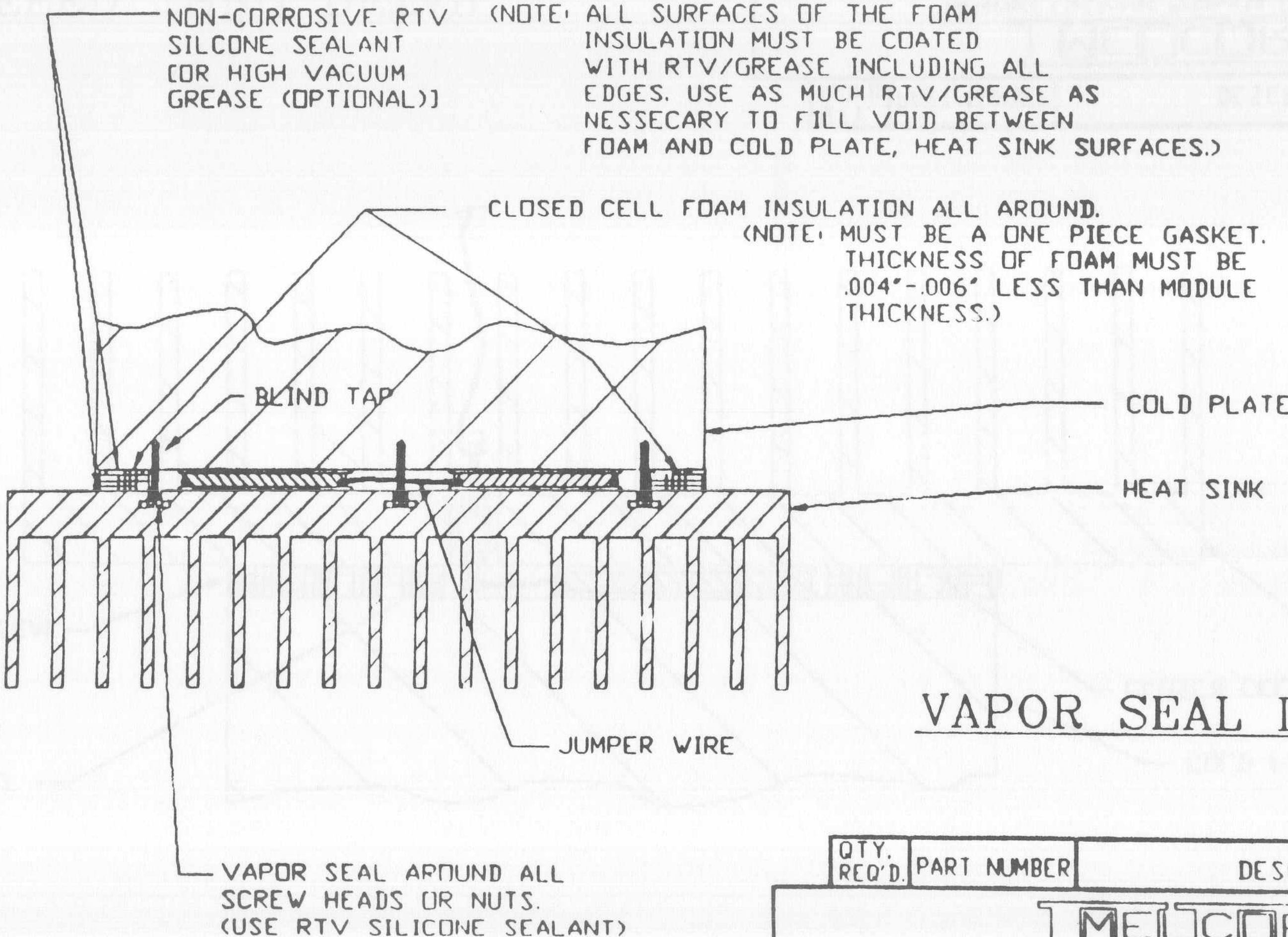
Drawing No. M88067 shows the details of a feed thru and vapor sealing system that can be used for maximum protection from the environment.

We feel that if you follow the recommendations shown in these drawings that you will see a significant improvement in performance. When testing an assembly of this type it is important to monitor temperature. Temperature of the cooling fluids, inlet and outlet temperatures as well as flow rates are necessary. This is true if either gas or liquid fluids are used. Input power to the T.E. device, both voltage and current will also help in determining the cause of potential problems.

In addition we have enclosed step by step procedures for assembling CP and FC modules, solderable (type TL) or Lapped modules to heatexchangers.

If you should require any further assistance, please do not hesitate contacting one of our engineers. Our many years of experience in working with customers ensuring reliable and efficient application of our products has proven to be essential to product success.

REVISIONS			
REV.	DESCRIPTION	DATE	BY
1	ADDED RTV NOTES	7/23/90	D.B.N.



VAPOR SEAL DETAIL

QTY. REQ'D.	PART NUMBER	DESCRIPTION	ITEM NO

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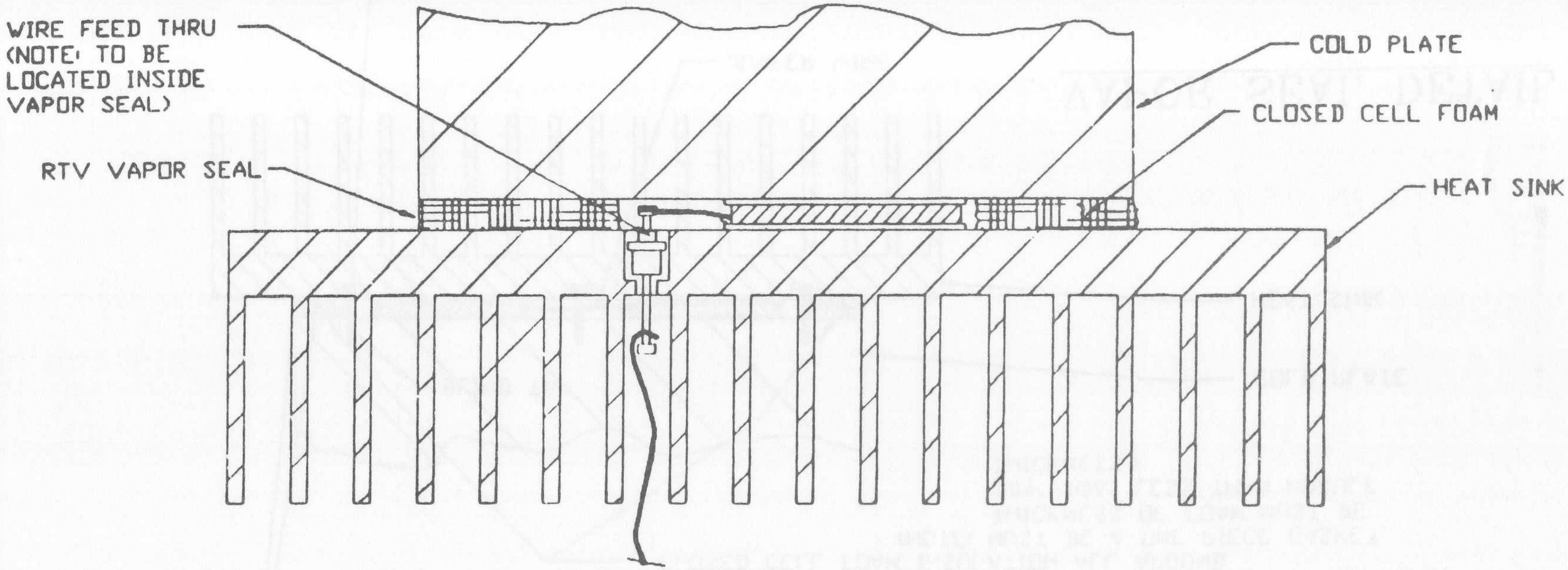
MATERIAL	VAPOR SEAL DETAIL				
FINISH SPECS	DATE 3/25/88	SCALE	DRAWN BY: DJR. CHECKED BY	DRAWING NUMBER M88066	REV 1

REVISIONS			
REV.	DESCRIPTION	DATE	BY
1	ADDED NOTES	7/23/90	D.B.N.



QTY. REQ'D.	PART NUMBER	DESCRIPTION	ITEM NO.

FEED THRU DETAIL

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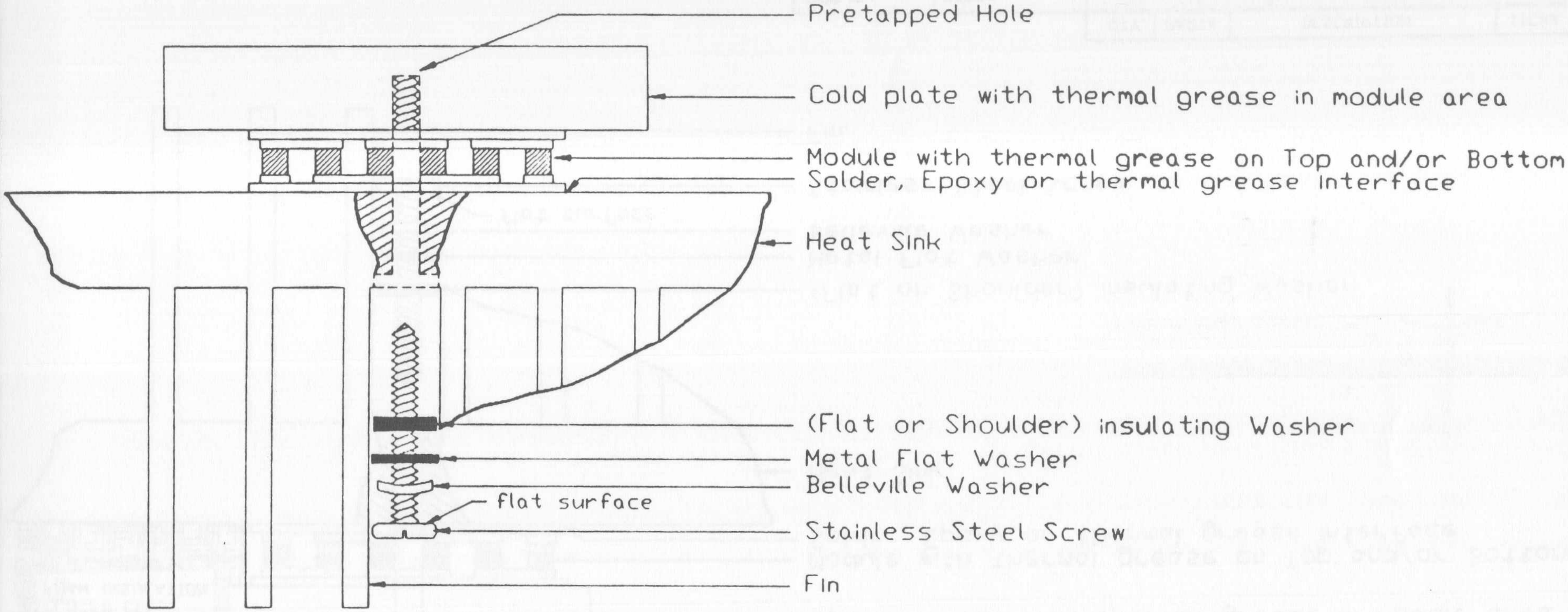
MATERIAL	FEED THRU DETAIL				
FINISH SPECS.	DATE 3/25/88	SCALE	DRAWN BY: PJR. CHECKED BY:	DRAWING NUMBER M88067	REV. 1

REVISIONS			
REV.	DESCRIPTION	DATE	BY
1	IMPROVED SCREW DETAIL	11/1/90	PSM



MOUNTING HARDWARE DETAIL

QTY.	PART#	DESCRIPTION	ITEM#

CONTROL DIM:

MATERIAL:

THIRD ANGLE PROJECTION

FINISH SPECS: UNLESS OTHERWISE SPECIFIED: REMOVE ALL BURRS AND SHARP EDGES.

DIMS ARE:

DO NOT SCALE DWG

APPROVALS	DATE
DRAWN BY: HSS	4/25/90
CHECKED BY:	
DESIGN ENGINEER	11/1/90
USED ON	
NEXT ASSEMBLY	

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990 SPRUCE ST. TRENTON, N.J. 08648

TITLE: MOUNTING HARDWARE DETAIL

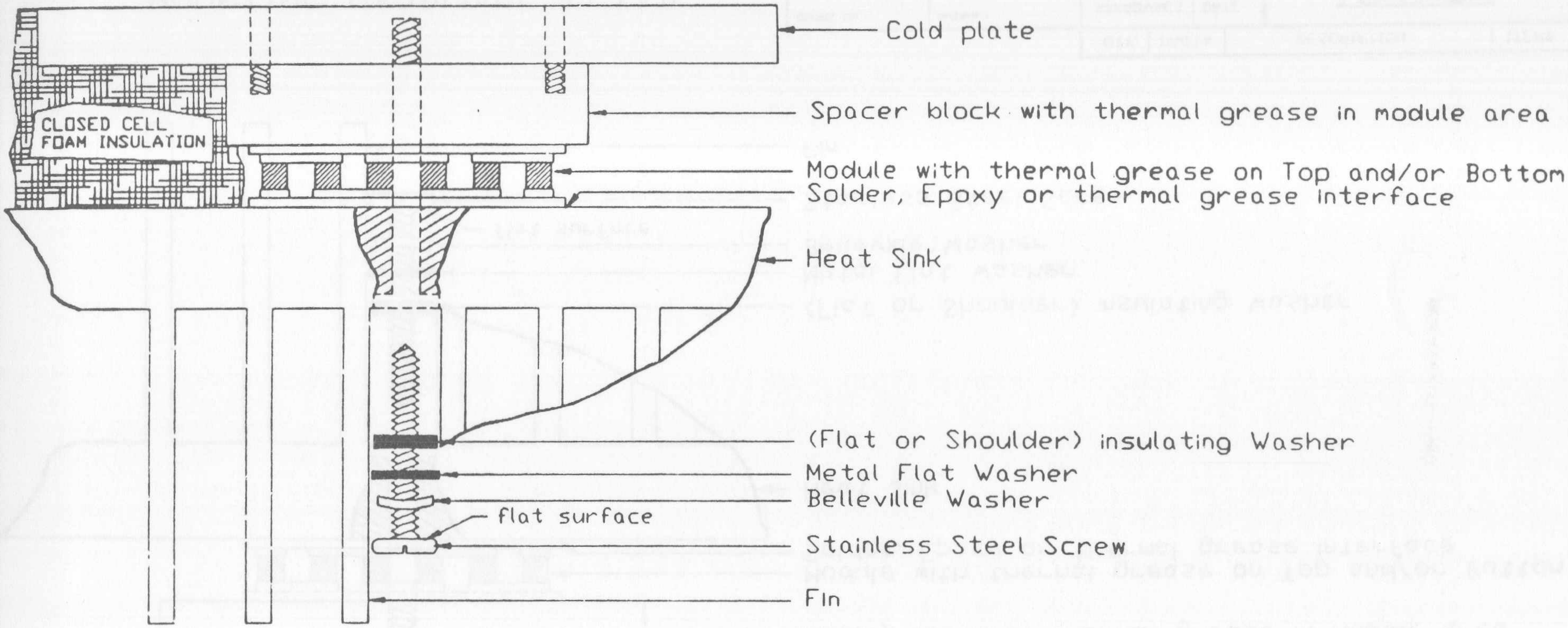
DRAWING NUMBER: M90117

SCALE:

SHEET:

REV. 1

REVISIONS			
REV.	DESCRIPTION	DATE	BY



SPACER BLOCK DETAIL

QTY.	PART#	DESCRIPTION	ITEM#

CONTROL DIM :	MATERIAL :	APPROVALS	DATE	MELCOR Materials Electronic Products Corporation 990 SPRUCE ST. TRENTON, N.J. 08648
THIRD ANGLE PROJECTION	FINISH SPECS: UNLESS OTHERWISE SPECIFIED REMOVE ALL BURRS AND SHARP EDGES. DIMS ARE:	DRAWN BY : HSS	4/25/90	
		CHECKED BY:		TITLE: SPACER BLOCK DETAIL
		DESIGN ENGINEER: [signature]	11/1/90	
		USED ON		DRAWING NUMBER : M90250
DO NOT SCALE DWG		NEXT ASSEMBLY		SCALE : / SHEET / REV.

Materials Electronic Products Corporation

Procedure For Assembly CP and FC (Type L) Lapped Modules To Heat Exchange Surfaces Refer to Illustrations On Reverse Side

IMPORTANT: When two or more Thermoelectric devices are mounted between a common plate, the thermoelectric devices thicknesses should vary no more than .0015-inches. Contact our Engineering Department for more information on close tolerance lapped thermoelectric devices.

Step 1. Prepare cold plate and heat sink surfaces as follows:
A) Grind or lap flat within +/- .001" in module area.
B) Locate bolt holes as close as possible to opposite edges of module (1/8" clearance recommended, 1/2" Maximum), in the same plane line as the heat sink fins. This orientation utilizes the additional structural strength of the fins to prevent bowing. Drill clearance holes on one surface and drill and tap opposite surface accordingly (see sketch). If platforming is used to increase distance between surfaces, performance is greater if platform is on cold side of system.
C) Remove all burrs, chips and foreign matter in thermoelectric module area.

Step 2. Thoroughly clean and degrease thermoelectric module, heat sink and cold surface.

Step 3. Apply a thin continuous film of thermal grease (Wakefield Engineering Type 120 or Dow Type 340) to module hot side surface and to module area on heat sink.

Step 4. Locate module on heat sink, hot side down.

Step 5. Gently oscillate module back and fourth, exerting uniform downward pressure, noting efflux of thermal compound around edges of module. Continue motion until resistance is felt.

Step 6. Repeat Step #3 for cold side surface and cold plate.

Step 7. Position cold plate on module.

Step 8. Repeat Step #5, sliding cold plate instead of module. Be particularly careful to maintain uniform pressure.

Step 9. Before bolting, best results are obtained by preloading in compression the cold plate/heat sink/module assembly, applying light load in line with center of module, using clamp or weights. For two module assemblies, use 3 screws located on module center line, with middle screw located between modules. To preload, torque middle screw first. Bolt carefully, by applying torque in small increments, alternating between screws. Use a torque limiting screw driver. Apply 8 to 12 pounds torque per bolt per square inch of module ceramic area (Examples: CP2-31-XX and CP1.4-71-XX are one square inch in area - apply 8 to 12 in. lbs.; CP2-15-XX and CP1.4-35-XX are 1/2 sq. inch area - apply 4 to 6 in. lbs.; FC0.6-32-XX and FC0.7-32-XX are 1/10 sq. inch area - apply 0.8 to 1.2 in. lbs.). Check torque after one hour and retighten if necessary. Use 4/40 or 6/32 Stainless Steel Screws, fibre insulating shoulder washers, and steel spring (Belleville or split lock type) washers (see sketch).

Notes:

1. To assure good thermal grease interfaces there should be no bowing of either surface due to torquing. To prevent bowing, apply less torque if one or both surfaces are less than 1/8 inch thick copper or 1/4 inch thick aluminum.

CAUTION

2. Lead wires are soldered to module tabs with bismuth/tin solder (136°C). If lead wire replacement is necessary, use bismuth/tin solder. DO NOT use lead/tin solder (180°C).

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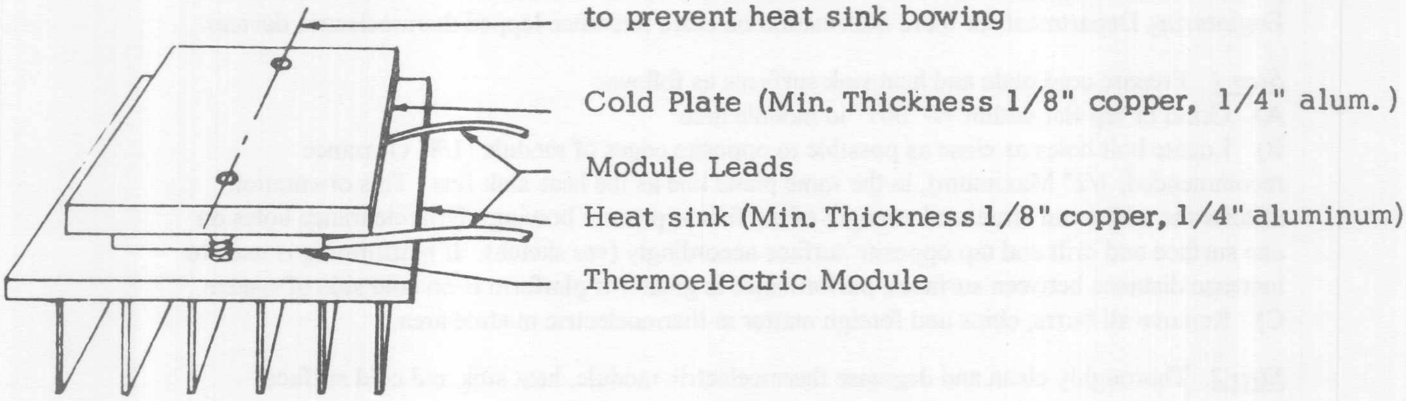
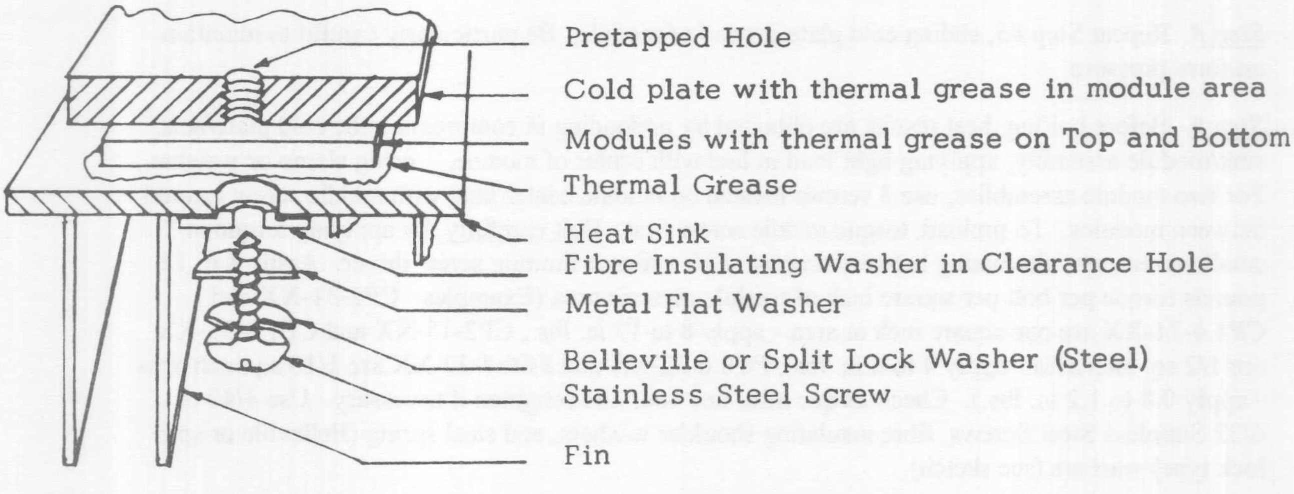


End View



Exploded Cross Section

Procedure For Assembling CP and FC Solderable Modules (Type TL) To Heat Exchangers

Refer To Illustrations on Reverse Side

Step 1 Prepare cold plate and heat sink surfaces by drilling clearance holes on one surface and drill and tap opposite accordingly (see sketch). If platforming is used to increase distance between surfaces, performance is greater if platform is on cold side of system.

Step 2 Grind or lap flat cold plate (within +/- .001") in module area. Thoroughly clean and degrease thermoelectric module, heat sink, and cold surface.

Step 3 Heat sink surface must be solderable (either copper or copper plated aluminum). Clean module area of heat sink surface by light abrasion and degrease thoroughly. Pretin with indium-tin eutectic type solder and flux provided.

Step 4 Module surface should be degreased and fluxed lightly. Heat pretinned and cleaned heat sink surface to 120 to 130°C. (250 to 265°F). Place module in position on surface, wait a few seconds for solder on module to melt and excess flux to boil out. When all solder is molten, module will have tendency to float on solder. Light swishing of module will enhance wetting. (Note: If after all solder is molten there is a slight dragging effect on the module, a deficiency of solder is indicated. Remove module and add additional solder to heat exchange surface. Cool unit and solidify solder.

If more than one module is used in the assembly, the flattened cold side surfaces of the module must be kept in a common plane during the soldering operation (Step #3). This can best be accomplished by first fastening the modules, cold face down and in proper array, to a ground flat plate o metal or graphite with double-faced tape. This assembly of modules and flat plate of metal or graphite with double-faced tape. This assembly of modules and flat plate facilitates soldering of the modules to the heat sink, while insuring that all module cold surfaces are maintained in a common plane and properly arrayed.

Step 5 After assembly cools, rinse thoroughly to remove all traces of flux residue.

Step 6 Assembly is now ready for bolting to cold plate. Apply a thin continuous film of thermal grease (Wakefield Engineering Type 120 or Dow Type 340) to module top surface and to module area on cold plate and mate surfaces. Gently oscillate module back and fourth, exerting uniform downward pressure, noting efflux of thermal compound around edges of module. Continue motion until resistance is felt.

Step 7 Before bolting, best results are obtained by preloading in compression the cold plate/heat sink/module assembly, applying light load in line with center of module, using clamp or weights. For two module assemblies, use 3 screws located on module center line, with middle screw located between modules. To preload, torque middle screw first. Bolt carefully, by applying torque in small increments, alternating between screws. Use a torque limiting screw driver. Apply 8 to 12 pounds torque per bolt per square inch of module ceramic area (Examples: CP2-31-XX and CP1.4-71-XX are one square inch in area - apply 8 to 12 in. lbs.; CP2-15-XX and CP1.4-35-XX are 1/2 sq. inch area - apply 4 to 6 in. lbs.; FC0.6-32-XX and FC0.7-32-XX are 1/10 sq. inch area - apply 0.8 to 1.2 in. lbs.). Check torque after one hour and retighten if necessary. Use 4/40 or 6/32 Stainless Steel Screws, fibre insulating shoulder washers, and steel spring (Belleville or split lock type) washers (see sketch).

CAUTION

Notes: 1.To assure good thermal grease interfaces there should be no bowing of either surface due to torquing. To prevent bowing, apply less torque if one or both surfaces are less than 1/8 inch thick copper or 1/4 inch thick aluminum.

2. Lead wires are soldered to module tabs with bismuth/tin solder (136°C). If lead wire replacement is necessary, use bismuth/tin solder. DO NOT use lead/tin solder (180°C).

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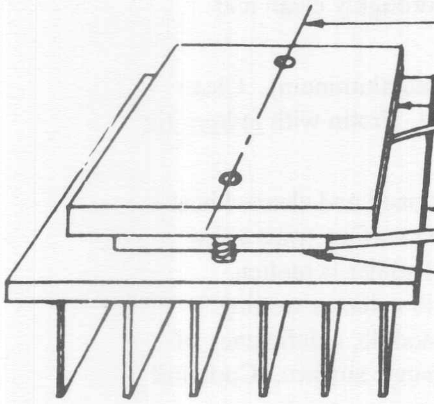
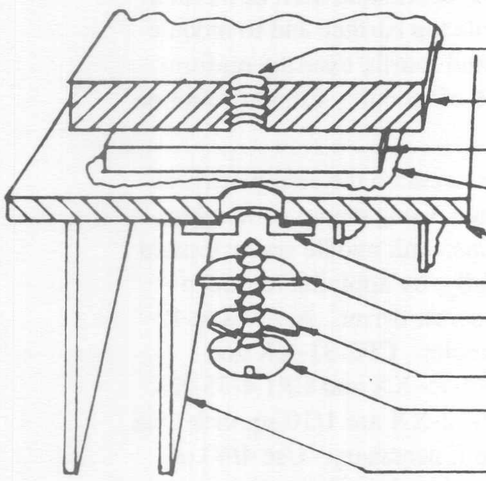
CAUTION: AT NO TIME SHOULD MODULE BE HEATED ABOVE 130° C. (276° F.)



End View



Exploded Cross Section

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Reliability & Mean Time Between Failures (MTBF)

Thermoelectric devices are highly reliable due to their solid state construction. Although reliability is somewhat application dependent, MTBF's calculated as a result of tests performed by various customers are on the order of 200,000 to 300,000 hours at room temperature. Elevated temperature (80°C) MTBF's are conservatively reported to be on the order of 100,000 hours. Field experience by hundreds of customers representing over 7,500,000 of our CP type modules and over 800,000 FC type modules during the last ten years have resulted in a failure return of less than 0.1%. Over 90% of all modules returned were found to be failures resulting from mechanical abuse or overheating on the part of the customer. Thus, less than one failure per 10,000 modules used in systems could be suspect of product defect. Therefore, the combination of proper handling, and proper assembly techniques will yield an extremely reliable system.

Historical failure analysis has generally shown the cause of failure as one of two types:

Mechanical damage as a result of improper handling or system assembly techniques.

Moisture:

Moisture must not penetrate into the thermoelectric module area. The presence of moisture will cause an electro-corrosion that will degrade the thermoelectric material, conductors and solders. Moisture can also provide an electrical path to ground causing an electrical short or hot side to cold side thermal short. A proper sealing method or dry atmosphere can eliminate these problems.

Shock and Vibration:

Thermoelectric modules in various types of assemblies have for years been used in different Military/Aerospace applications, Thermoelectric devices have been successfully subjected to shock and vibration requirements for aircraft, ordinance, space vehicles, shipboard use and most other such systems. While a thermoelectric device is quite strong in both tension and compression, it tends to be relatively weak in shear. When in a sever shock or vibration environment, care should be taken in the design of the assembly to insure "compressive loading" of thermoelectric devices.

Mechanical Mounting:

A common failure mode for thermoelectric modules is uneven compression forces induced by improper torqing, bolting patterns, and mechanical conditions of heat exchangers.. The polycrystalline thermoelectric material exhibit less strength perpendicular to the length (growth axis) than the horizontal axis. thus, the thermoelectric elements are quite strong in compressive strength and tend to be weak in the shear direction. During assembly un-even torquing or un-flat heat exchangers can cause severe shear forces. Recommended compression values are 150 pounds/sq. inch. (See assembly instructions for proper mounting techniques)

Inadvertent overheating of the module.

The direct soldering process does result in temperature restriction for operation or storage of the modules. At temperatures above 80°C two phenomena seriously reduce useful life:

Above 80°C copper diffusion into the thermoelements occurs due to increasing solid solubility in the thermoelectric material and increasing diffusion rate. At 100 - 110°C the combined solubility and diffusion rate could result in approximately 25% loss of device performance within 100 hours.

Above 85°C in the soldering process (using Bismuth-Tin alloy) small amounts of selenium, tellurium, antimony and nickel are inherently dissolved into the bismuth-tin solder. Although the melting point of the base solder is 136°C, the combined mixture of all elements results in either a minute eutectic phase or a highly effective solid state reaction occurring at above 85°C that starts to delaminate the ends of the thermoelements by physical penetration between cleavage planes in the thermoelectric material. This results in a mechanical failure of the interface.

December 1, 1992

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DEVICE PERFORMANCE FORMULAE

Heat Pumped at Cold Surface:

$$Q_c = 2N\,[\,\alpha\, I\, T_c - I^2 \rho / 2G - \kappa\, \Delta T\, G\,] \qquad (watts)$$

Voltage:

$$V = 2N\,[\,I \rho / G + \alpha\, \Delta T\,] \qquad (volts)$$

Maximum Current:

$$I_{max} = (\kappa\, G / \alpha)\,[\,\sqrt{1 + 2\, Z\, T_h} - 1\,] \qquad (amps)$$

Optimum Current:

$$I_{opt} = \kappa\, \Delta T\, G\,(\,1 + \sqrt{1 + Z\bar{T}}\,)\,/\,(\,\alpha\, \bar{T}\,) \qquad (amps)$$

Optimum COP (calculated at I_{opt})

$$COPopt = (\bar{T} / \Delta T)\left(\frac{\sqrt{1 + Z\bar{T}} - 1}{\sqrt{1 + Z\bar{T}} + 1}\right) - 1/2$$

Maximum ΔT with Q = 0

$$\Delta T_{max} = T_h - (\,\sqrt{1 + 2\, Z\, T_h} - 1\,)\,/\,Z \qquad (°K)$$

Geometry Factor (G)

TEC	G
FC 0.5 -XX- 05	0.016
FC 0.6 -XX- 06	0.024
FC 0.6 -XX- 05	0.030
FC 0.7 -XX- 04	0.040
CP 0.8 -XX- 06	0.042
CP 0.8 -XX- 05	0.052
CP 1.0 -XX- 08	0.052
CP 1.0 -XX- 06	0.064
CP 1.0 -XX- 05	0.078
CP 1.4 -XX- 10	0.078
CP 1.4 -XX- 06	0.117
CP 1.4 -XX- 045	0.162
CP 2 -XX- 10	0.193
CP 2 -XX- 06	0.296
CP 2.8 -XX- 06	0.496
CP 5 -XX- 10	0.802
CP 5 -XX- 06	1.255

Miscellaneous Expressions:

T_h	=	Hot Side Temperature	(°K)
T_c	=	Cold Side Temperature	(°K)
ΔT	=	$T_h - T_c$	(°K)
$\bar{T}$	=	$1/2\,(T_h + T_c)$	(°K)
G	=	Area / Length of T.E. element	*(cm)*
N	=	Number of Thermocouples	
I	=	Current	*(amps)*
COP	=	Coefficient of Performance = $Q_c / I\,V$	
α	=	Seebeck coefficient	*(volts/°K)*
ρ	=	Resistivity	*(ohm-cm)*
κ	=	Thermal Conductivity	*(watt/cm °K)*
Z	=	$\alpha^2 / \rho\,\kappa$	(Figure of Merit $°K^{-1}$)
S	=	$2\alpha\, N$	(device Seebeck voltage *volts/°K*)
R	=	$2\rho\, N / G$	(device electrical resistance *ohms*)
K	=	$2\kappa\, N\, G$	(device thermal conductance *watt/°K*)

Material Property Coefficients

$\alpha = (\,\alpha_0 + \alpha_1\bar{T} + \alpha_2\bar{T}^2\,) \times 10^{-9}$ *volts / °K*

α_0	=	22224.0
α_1	=	930.6
α_2	=	-0.9905

$\rho = (\,\rho_0 + \rho_1\bar{T} + \rho_2\bar{T}^2\,) \times 10^{-8}$ *ohm - cm*

ρ_0	=	5112.0
ρ_1	=	163.4
ρ_2	=	0.6279

$\kappa = (\,\kappa_0 + \kappa_1\bar{T} + \kappa_2\bar{T}^2\,) \times 10^{-6}$ *watt / cm °K*

κ_0	=	62605.0
κ_1	=	-277.7
κ_2	=	0.4131

Z = $\alpha^2 / \rho\kappa$ $°K^{-1}$

Typical material parameters @ $\bar{T}$ = 296°K:

α	=	2.0×10^{-4} *volts/°K*
ρ	=	1.0×10^{-3} *Ω-cm*
κ	=	1.5×10^{-2} *watt/cm-°K*
Z	=	2.67×10^{-3} *°K^{-1}*

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THERMOELECTRIC POWER GENERATION DEVICE SELECTION FORMULAE

E_L	=	required load voltage
I_L	=	required load amps
T_h	=	hot side temperature of thermoelectric (°C)
T_c	=	cold side temperature of thermoelectric (°C)
ΔT	=	$T_h - T_c$
N	=	number of thermoelectric couples
G	=	Geometry Factor (see Module Specification)

1) TO DETERMINE # OF COUPLES REQUIRED (N)

$$N = \frac{5{,}000 \times E_L}{\Delta T}$$

2) TO DETERMINE MODULE TYPE (G)

$$G = \frac{10 \times I_L}{\Delta T}$$

EXAMPLE:

The generator requirements are as follows:
Provide 2.0 volts at 0.5 amps with a heat source temperature of 85°C, and an ambient of 0°C.

NOTE: The actual ΔT across the thermoelectric ($T_h - T_c$), may be smaller than the ΔT of the system (heat source - ambient), due to thermal losses at the interfaces through radiation, conduction, etc. These losses must be taken into account. For this example we'll assume losses of 10°C at each interface, resulting in $T_h = 75$°C, $T_c = 10$°C, $\Delta T = 65$°C.

E_L	=	2.0 V
I_L	=	0.5 A
ΔT	=	65°C

1) DETERMINE # OF COUPLES REQUIRED (N)

$$N = \frac{5{,}000 \times 2.0}{65} = \mathbf{153.8}$$

2) DETERMINE MODULE TYPE (G)

$$G = \frac{10 \times 0.5}{65} = \mathbf{0.077}$$

3) SELECT THE THERMOELECTRIC(S)

Couples (N) = _ _ _._ - 154 - _ _ _
G ≈ CP 1.0 - XX - 05L (from Module Specifications, G = 0.078)
CP 1.0 - 154 - 05L

NOTE: The CP1.0-154-05L is not a standard MELCOR module, so a combination of devices is required.

SUGGESTION: Two CP1.0-71-05L — N = 142, G = 0.078
One CP1.0-127-05L and one CP1.0-31-05L — N = 158, G = 0.078

EFFICIENCY:

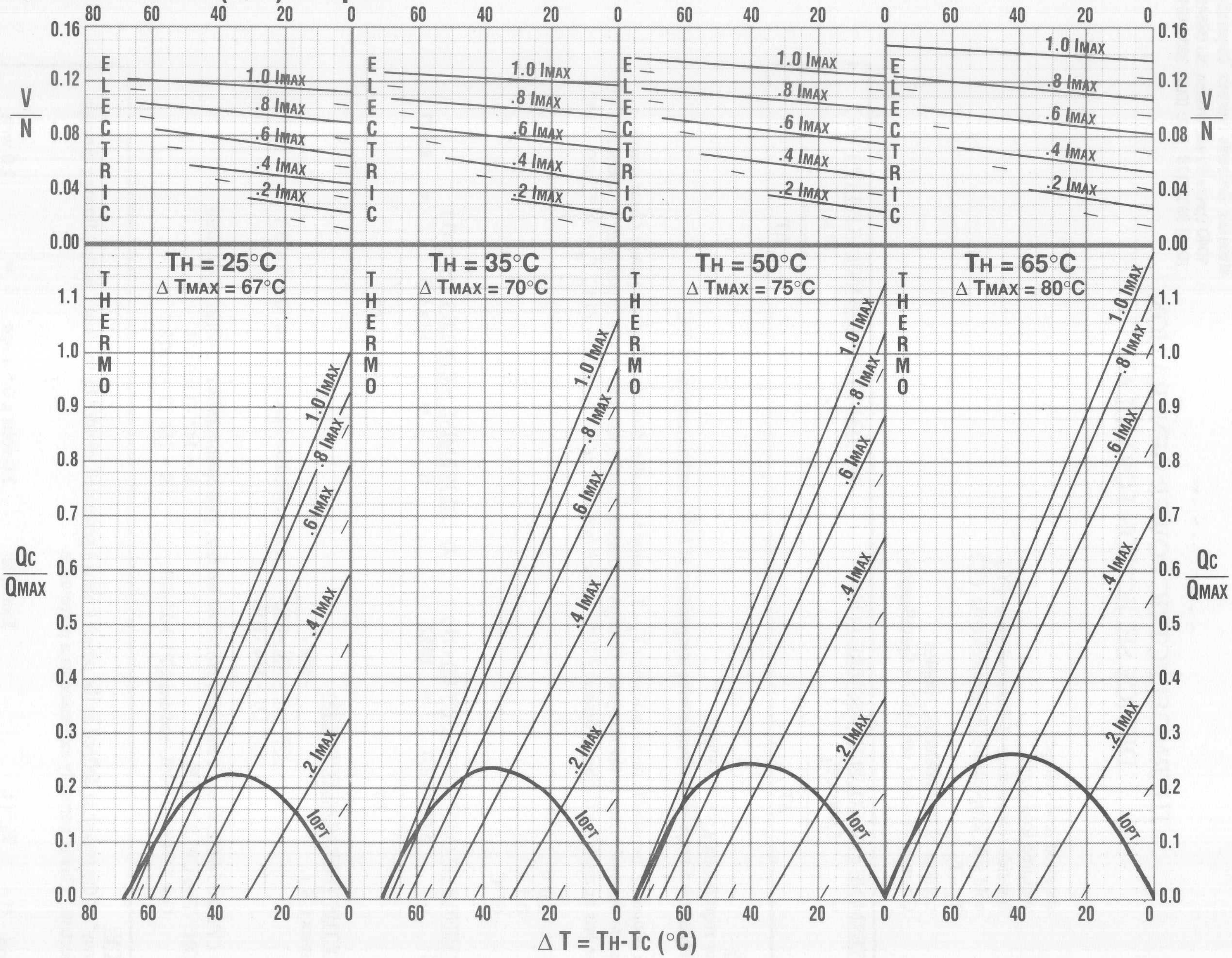
The "Efficiency" of the system is defined as the power (watts) generated, divided by the heat (watts) flowing through the thermoelectric. This is normally expressed as a percentage.

$Q_{load} = E_L \times I_L$ Example: 2.0 volts x 0.5 amps = 1.0 watt

$Q_{heat} = 0.03 (N \times \Delta T \times G)$ Example: 0.03 (158 x 65 x 0.078) = 24.03 watts

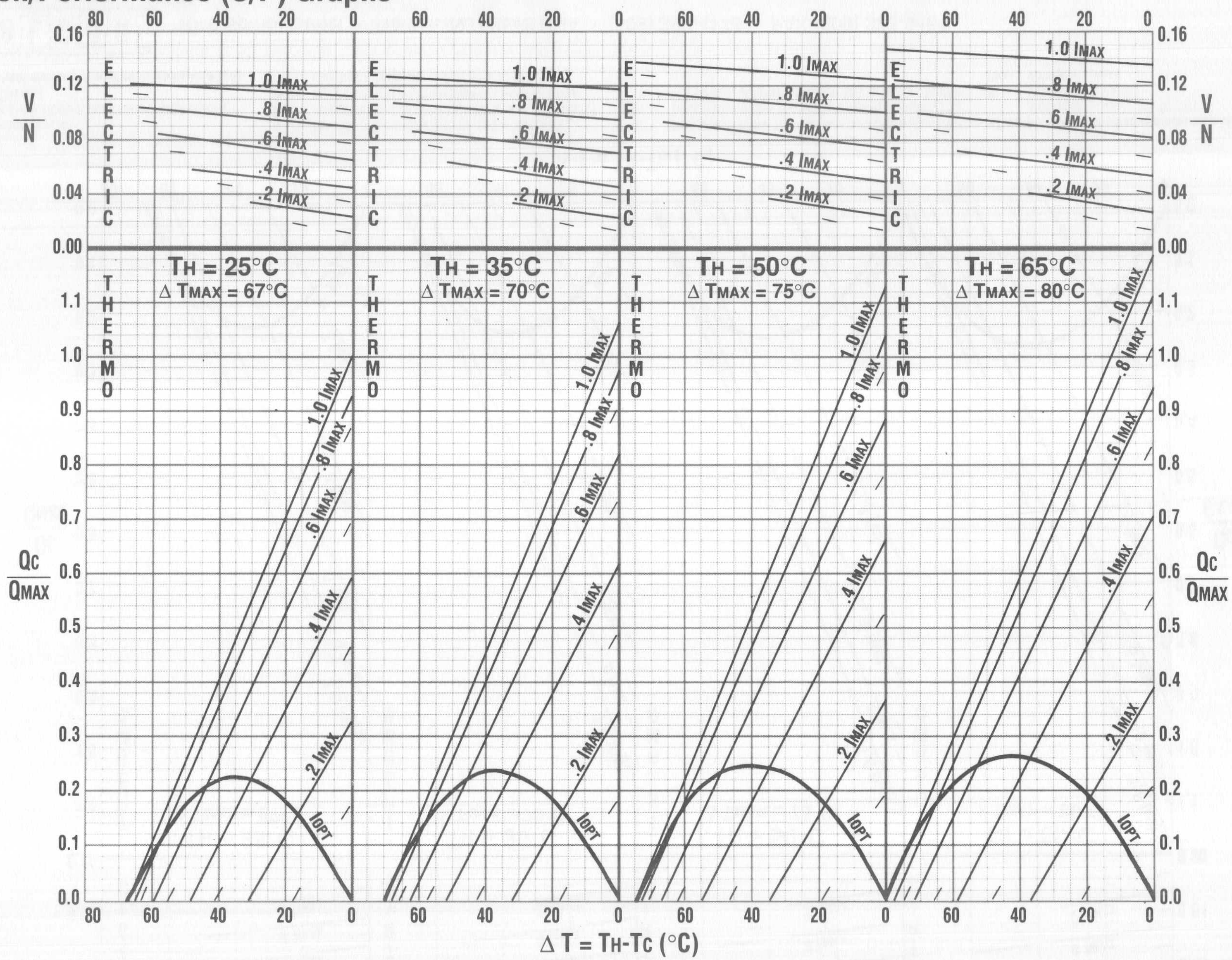
$$\text{Efficiency} = \frac{1.0}{24.03} = 0.042 = 4.2\%$$

Selection/Performance (S/P) Graphs



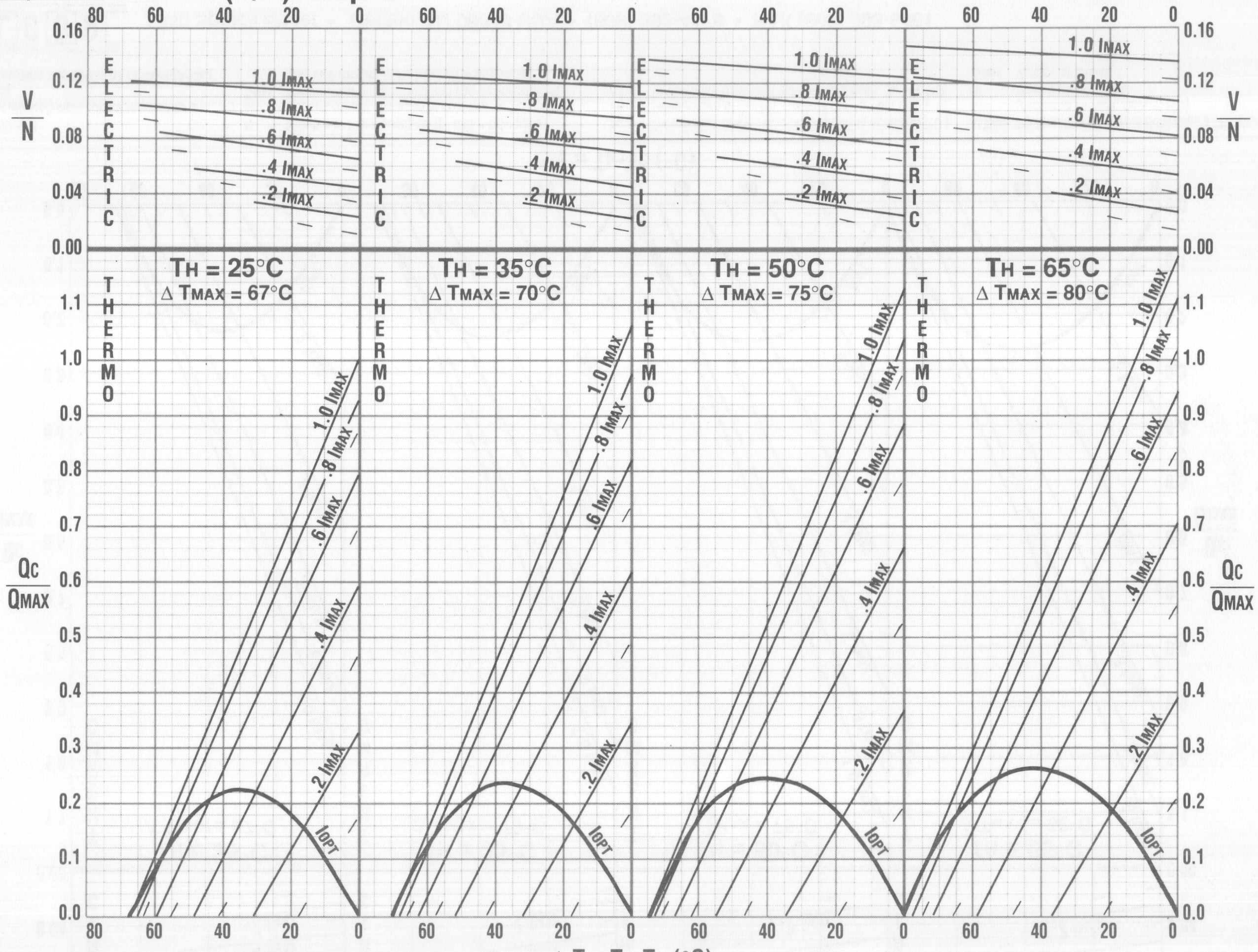
I	Input current [Amps]	N	Number of thermocouples (p- and n-type pairs)	TC	Temperature of the TEC cold face during operation [°C]	ΔTMAX	Maximum temperature difference a TEC can achieve (occurs at I = IMAX, QC = 0) [°C]
IOPT	Optimum (most efficient) input current required for a given ΔT [Amps]	QC	Amount of heat absorbed at cold face of TEC [Watts]	TH	Temperature of the TEC hot face during operation [°C]	V	Input Voltage [Volts]
IMAX	Input current resulting in greatest ΔT (ΔTMAX) [Amps]	QMAX	Maximum amount of heat that can be absorbed at cold face (occurs at I = IMAX, ΔT = 0) [Watts]	ΔT	Temperature difference between TEC faces, TH - TC [°C]	VMAX	Voltage at ΔTMAX

Selection/Performance (S/P) Graphs



I	Input current [Amps]
IOPT	Optimum (most efficient) input current required for a given ΔT [Amps]
IMAX	Input current resulting in greatest ΔT (ΔTMAX) [Amps]
N	Number of thermocouples (p- and n-type pairs)
Qc	Amount of heat absorbed at cold face of TEC [Watts]
QMAX	Maximum amount of heat that can be absorbed at cold face (occurs at I = IMAX, ΔT = 0) [Watts]
Tc	Temperature of the TEC cold face during operation [°C]
TH	Temperature of the TEC hot face during operation [°C]
ΔT	Temperature difference between TEC faces, TH - Tc [°C]
ΔTMAX	Maximum temperature difference a TEC can achieve (occurs at I = IMAX, Qc = 0) [°C]
V	Input Voltage [Volts]
VMAX	Voltage at ΔTMAX

Selection/Performance (S/P) Graphs



I Input current [Amps]
IOPT Optimum (most efficient) input current required for a given ΔT [Amps]
IMAX Input current resulting in greatest ΔT (ΔTMAX) [Amps]
N Number of thermocouples (p- and n-type pairs)
QC Amount of heat absorbed at cold face of TEC [Watts]
QMAX Maximum amount of heat that can be absorbed at cold face (occurs at I = IMAX, ΔT = 0) [Watts]
TC Temperature of the TEC cold face during operation [°C]
TH Temperature of the TEC hot face during operation [°C]
ΔT Temperature difference between TEC faces, TH - TC [°C]
ΔTMAX Maximum temperature difference a TEC can achieve (occurs at I = IMAX, QC = 0) [°C]
V Input Voltage [Volts]
VMAX Voltage at ΔTMAX

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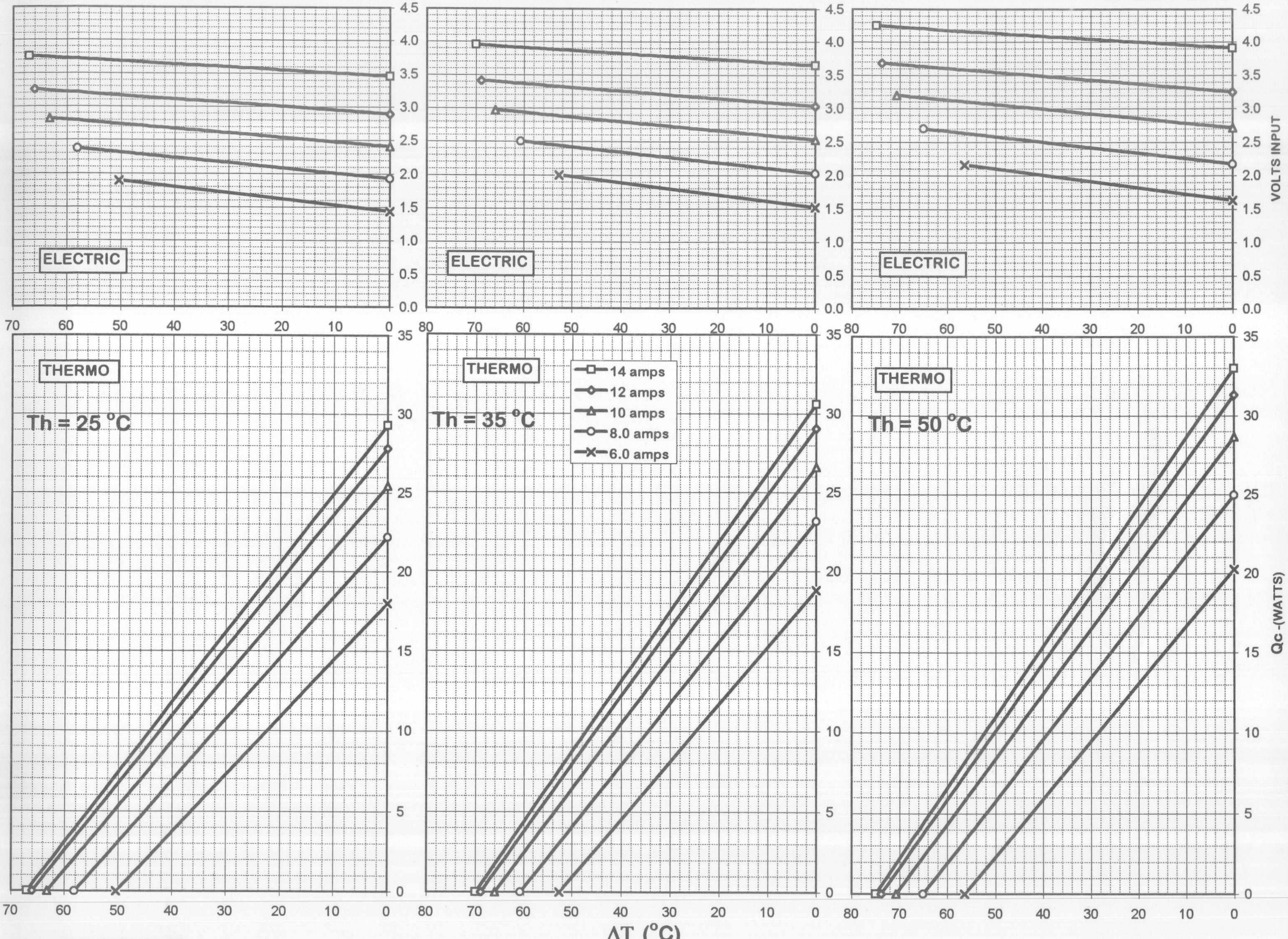
MELCOR THERMOELECTRICS

PERFORMANCE GRAPH

CP 2-31-06 L



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